

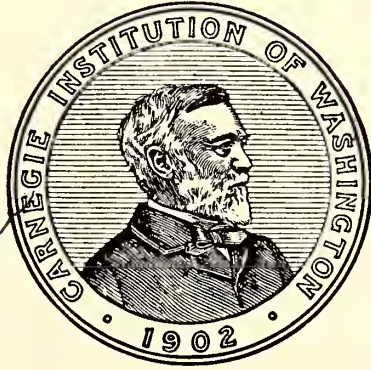
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CARNEGIE INSTITUTION OF WASHINGTON

YEAR BOOK No. 41

July 1, 1941—June 30, 1942

With Administrative Reports through December 18, 1942



*Copy for
President's Office*

CARNEGIE INSTITUTION OF WASHINGTON
WASHINGTON, D. C.

1942

THE LORD BALTIMORE PRESS, BALTIMORE, MARYLAND

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PRESIDENT AND TRUSTEES

PRESIDENT

VANNEVAR BUSH

BOARD OF TRUSTEES

W. CAMERON FORBES, *Chairman*
WALTER S. GIFFORD, *Vice-Chairman*
FREDERIC A. DELANO, *Secretary*

THOMAS BARBOUR	HERBERT HOOVER	HENNING W. PRENTIS, JR.
JAMES F. BELL	WALTER A. JESSUP	ELIHU ROOT, JR.
ROBERT WOODS BLISS	FRANK B. JEWETT	HENRY R. SHEPLEY
LINDSAY BRADFORD	ALFRED L. LOOMIS	RICHARD P. STRONG
FREDERIC A. DELANO	ROSWELL MILLER	CHARLES P. TAFT
HOMER L. FERGUSON	HENRY S. MORGAN	JAMES W. WADSWORTH
W. CAMERON FORBES	SEELEY G. MUDD	FREDERIC C. WALCOTT
WALTER S. GIFFORD	JOHN J. PERSHING	LEWIS H. WEED

Executive Committee

W. CAMERON FORBES, <i>Chairman</i>		
VANNEVAR BUSH	WALTER S. GIFFORD	FREDERIC C. WALCOTT
FREDERIC A. DELANO	WALTER A. JESSUP	LEWIS H. WEED
	HENRY R. SHEPLEY	

Finance Committee

FREDERIC C. WALCOTT, <i>Chairman</i>	
LINDSAY BRADFORD	FRANK B. JEWETT
WALTER S. GIFFORD	ELIHU ROOT, JR.

Auditing Committee

FREDERIC A. DELANO, <i>Chairman</i>	
ROBERT WOODS BLISS	JAMES W. WADSWORTH

STANDING COMMITTEES FOR THE YEAR 1943

Committee on Astronomy

HERBERT HOOVER, <i>Chairman</i>	
WALTER S. GIFFORD	SEELEY G. MUDD
ROSWELL MILLER	ELIHU ROOT, JR.

Committee on Terrestrial Sciences

FRANK B. JEWETT, <i>Chairman</i>	
FREDERIC A. DELANO	HENRY S. MORGAN
HOMER L. FERGUSON	FREDERIC C. WALCOTT

Committee on Biological Sciences

LEWIS H. WEED, <i>Chairman</i>	
THOMAS BARBOUR	WALTER A. JESSUP
JAMES F. BELL	ALFRED L. LOOMIS

Committee on Historical Research

HENRY R. SHEPLEY, <i>Chairman</i>	
ROBERT WOODS BLISS	CHARLES P. TAFT
RICHARD P. STRONG	JAMES W. WADSWORTH

FORMER PRESIDENTS AND TRUSTEES

PRESIDENTS

DANIEL COIT GILMAN, 1902-04

ROBERT SIMPSON WOODWARD, 1904-20

JOHN CAMPBELL MERRIAM, *President* 1921-38; *President Emeritus* 1939-

TRUSTEES

ALEXANDER AGASSIZ	1904-05	WAYNE MACVEAGH	1902-07
GEORGE J. BALDWIN	1925-27	ANDREW J. MELLON	1924-37
JOHN S. BILLINGS	1902-13	DARIUS O. MILLS	1902-09
ROBERT S. BROOKINGS	1910-29	S. WEIR MITCHELL	1902-14
JOHN L. CADWALADER	1903-14	ANDREW J. MONTAGUE	1907-35
WILLIAM W. CAMPBELL	1929-38	WILLIAM W. MORROW	1902-29
JOHN J. CARTY	1916-32	WILLIAM CHURCH OSBORN	1927-34
WHITEFOORD R. COLE	1925-34	JAMES PARMELEE	1917-31
CLEVELAND H. DODGE	1903-23	WM. BARCLAY PARSONS	1907-32
WILLIAM E. DODGE	1902-03	STEWART PATON	1916-42
CHARLES P. FENNER	1914-24	GEORGE W. PEPPER	1914-19
SIMON FLEXNER	1910-14	HENRY S. PRITCHETT	1906-36
WILLIAM N. FREW	1902-15	ELIHU ROOT	1902-37
LYMAN J. GAGE	1902-12	JULIUS ROSENWALD	1929-31
CASS GILBERT	1924-34	MARTIN A. RYERSON	1908-28
FREDERICK H. GILLETT	1924-35	THEOBALD SMITH	1914-34
DANIEL C. GILMAN	1902-08	JOHN C. SPOONER	1902-07
JOHN HAY	1902-05	WILLIAM BENSON STOREY	1924-39
MYRON T. HERRICK	1915-29	WILLIAM H. TAFT	1906-15
ABRAM S. HEWITT	1902-03	WILLIAM S. THAYER	1929-32
HENRY L. HIGGINSON	1902-19	CHARLES D. WALCOTT	1902-27
ETHAN A. HITCHCOCK	1902-09	HENRY P. WALCOTT	1910-24
HENRY HITCHCOCK	1902-02	WILLIAM H. WELCH	1906-34
WILLIAM WIRT HOWE	1903-09	ANDREW D. WHITE	1902-03
CHARLES L. HUTCHINSON	1902-04	EDWARD D. WHITE	1902-03
SAMUEL P. LANGLEY	1904-06	HENRY WHITE	1913-27
CHARLES A. LINDBERGH	1934-39	GEORGE W. WICKERSHAM	1909-36
WILLIAM LINDSAY	1902-09	ROBERT S. WOODWARD	1905-24
HENRY CABOT LODGE	1914-24	CARROLL D. WRIGHT	1902-08
SETH LOW	1902-16		

Besides the names enumerated above, the following were ex-officio members of the Board of Trustees under the original charter, from the date of organization until April 28, 1904: the President of the United States, the President of the Senate, the Speaker of the House of Representatives, the Secretary of the Smithsonian Institution, the President of the National Academy of Sciences.

STAFF OF INVESTIGATORS FOR THE YEAR 1942

ASTRONOMY

MOUNT WILSON OBSERVATORY

Organized in 1904; George E. Hale, Director 1904-1923, Honorary Director 1923-1936

WALTER S. ADAMS, <i>Director</i>	ROBERT B. KING
ALFRED H. JOY, <i>Secretary</i>	PAUL W. MERRILL
ARTHUR S. KING, <i>Supt. Physical Laboratory</i>	RUDOLPH MINKOWSKI
JOHN A. ANDERSON	SETH B. NICHOLSON
WALTER BAADE	EDISON PETTIT
HAROLD D. BABCOCK	ROBERT S. RICHARDSON
WILLIAM H. CHRISTIE	ROSCOE F. SANFORD
THEODORE DUNHAM, JR.	GUSTAF STRÖMBERG
JOSEPH HICKOX	ADRIAAN VAN MAANEN
EDISON HOGE	OLIN C. WILSON
EDWIN P. HUBBLE	RALPH E. WILSON
MILTON L. HUMASON	

TERRESTRIAL SCIENCES

GEOPHYSICAL LABORATORY

Organized in 1906, opened in 1907; Arthur L. Day, Director 1907-1936

L. H. ADAMS, <i>Director</i>	G. W. MOREY
J. S. BURLEW	E. F. OSBORN
ALLEN CROCKER (resigned)	C. S. PIGGOT
J. L. ENGLAND	EUGENE POSNJAK
R. E. GIBSON	H. S. ROBERTS
R. W. GORANSON	J. F. SCHAIRER
J. W. GREIG	E. S. SHEPHERD
EARL INGERSON	GEORGE TUNELL
F. C. KRACEK	W. D. URRY
O. H. LOEFFLER	F. E. WRIGHT
H. E. MERWIN	E. G. ZIES

DEPARTMENT OF TERRESTRIAL MAGNETISM

Organized in 1904; L. A. Bauer, Director 1904-1929

J. A. FLEMING, <i>Director</i>	A. G. MCNISH
O. H. GISH, <i>Assistant Director</i>	R. C. MEYER
P. H. ABELSON	W. C. PARKINSON
C. J. ARONSON	R. B. ROBERTS
L. V. BERKNER	W. J. ROONEY
R. C. COILE (resigned)	W. E. SCOTT
S. E. FORBUSH	S. L. SEATON
G. K. GREEN	K. L. SHERMAN
L. R. HAFSTAD	W. F. STEINER
N. P. HEYDENBURG	O. W. TORRESON
E. A. JOHNSON	M. A. TUVE
H. F. JOHNSTON	E. H. VESTINE
M. W. JONES	G. R. WAIT
P. G. LEDIG	H. W. WELLS

BIOLOGICAL SCIENCES

DIVISION OF PLANT BIOLOGY

Desert Laboratory, opened in 1903, became headquarters of Department of Botanical Research in 1905. Name changed to Laboratory for Plant Physiology in 1923; reorganized in 1928 as Division of Plant Biology, including Ecology.

H. A. SPOEHR, *Chairman*
JENS CLAUSEN
WILLIAM M. HIESEY
DAVID D. KECK
WINSTON M. MANNING

EMMETT V. MARTIN
H. W. MILNER
FORREST SHREVE
JAMES H. C. SMITH
HAROLD H. STRAIN

DEPARTMENT OF EMBRYOLOGY

Organized in 1914; Franklin P. Mall, Director 1914–1917; George L. Streeter, Director 1918–1940

GEORGE W. CORNER, *Director*
ROBERT K. BURNS, JR.
LOUIS B. FLEXNER
ALFRED GELLHORN, *Fellow*

CHESTER H. HEUSER, *Curator of the Embryological Collection*
MARGARET R. LEWIS
SAMUEL R. M. REYNOLDS

DEPARTMENT OF GENETICS

Station for Experimental Evolution, opened in 1904, combined with Eugenics Record Office in 1921 to form Department of Genetics. Charles B. Davenport, Director 1904–1934; A. F. Blakeslee, Director 1935–1941.

M. DEMEREC, *Acting Director*
AMOS G. AVERY
A. DOROTHY BERGNER
UGO FANO, *Fellow*
B. P. KAUFMANN
E. C. MACDOWELL

JAMES S. POTTER
OSCAR RIDDLE
SOPHIA SATINA
MORRIS STEGGERDA
H. E. WARMKE

NUTRITION LABORATORY

Organized in 1907, opened in 1908; F. G. Benedict, Director 1907–1937

T. M. CARPENTER, *Acting Director*
V. COROPATCHINSKY

ROBERT C. LEE

HISTORICAL RESEARCH

DIVISION OF HISTORICAL RESEARCH

Department of Historical Research organized in 1903; Andrew C. McLaughlin, Director 1903–1905, J. Franklin Jameson, Director 1905–1928. In 1930 this Department was incorporated as the Section of United States History in a new Division of Historical Research.

A. V. KIDDER, *Chairman*

Section of Aboriginal American History

SYLVANUS G. MORLEY
EARL H. MORRIS
H. E. D. POLLOCK
KARL RUPPERT
ANNA O. SHEPARD
EDWIN M. SHOOK
A. LEDYARD SMITH
ROBERT E. SMITH
GUSTAV STRÓMSVIK
SOL TAX
J. ERIC S. THOMPSON
ALFONSO VILLA R.

Section of Post-Columbian American History

ELEANOR B. ADAMS
ROBERT S. CHAMBERLAIN
RALPH L. ROYS
FRANCE V. SCHOLES
LEO F. STOCK

Section of the History of Science

GEORGE SARTON
ALEXANDER POGO

RESEARCH ASSOCIATES

MARION E. BLAKE, Archaeology
PAUL S. CONGER, Biology
NEWTON B. DRURY, Study of Primitive Areas

FRANK A. PERRET, Geophysics
JOHN T. TATE, Physics

RESEARCH ASSOCIATES ENGAGED IN POST-RETIREMENT STUDIES

A. F. BLAKESLEE, Genetics
FREDERICK H. SEARES, Astronomy

GEORGE L. STREETER, Embryology

RESEARCH ASSOCIATES CONNECTED WITH OTHER INSTITUTIONS

ERNEST B. BABCOCK (University of California), Genetics
V. BJERKNES (University of Oslo), Meteorology
EDWARD L. BOWLES (Massachusetts Institute of Technology), Physics
JOSEPH C. BOYCE (Massachusetts Institute of Technology), Physics
E. H. BRAMHALL (University of Alaska), Terrestrial Magnetism
G. BREIT (University of Wisconsin), Physics
ROBERT B. BRODE (University of California), Physics
DIRK BROUWER (Yale University), Astronomy
JOHN P. BUWALDA (California Institute of Technology), Geology and Paleontology
W. E. CASTLE (University of California), Biology
RALPH W. CHANEY (University of California), Paleobotany
A. H. COMPTON (University of Chicago), Physics
L. S. CRESSMAN (University of Oregon), Archaeology
TH. DOBZHANSKY (Columbia University), Genetics
CHARLES ELTON (Oxford University), Climatology
G. GAMOW (George Washington University), Physics
FRANK T. GUCKER, JR. (Northwestern University), Chemistry
ROSS GUNN (United States Naval Research Laboratory), Terrestrial Magnetism
ARTHUR T. HERTIG (Boston Lying-in Hospital), Embryology
H. H. HESS (Princeton University), Geophysics
VICTOR F. HESS (Fordham University), Physics
A. HOLLAENDER (National Institute of Health), Genetics
EDGAR B. HOWARD (University of Pennsylvania), Archaeology and Paleontology
JAMES H. JEANS (Royal Society of London), Astronomy
EINAR JENSEN (University of Oslo), Geophysics
THOMAS H. JOHNSON (Bartol Research Foundation), Physics
ELLIOTT P. JOSLIN (New England Deaconess Hospital), Nutrition
REMINGTON KELLOGG (United States National Museum), Paleontology
S. A. KORFF (Bartol Research Foundation), Physics
E. A. LOWE (The Institute for Advanced Study), Paleography
EDWIN D. MCKEE (United States National Park Service), Geology and Paleontology
CHARLES W. METZ (University of Pennsylvania), Biology
ROBERT A. MILLIKAN (California Institute of Technology), Physics
S. A. MITCHELL (University of Virginia), Astronomy
T. H. MORGAN (California Institute of Technology), Biology
WALTER H. NEWHOUSE (Massachusetts Institute of Technology), Geophysics
WILSON M. POWELL (University of California), Physics
ROBERT REDFIELD (University of Chicago), Anthropology
HENRY N. RUSSELL (Princeton University), Astronomy
H. C. SHERMAN (Columbia University), Nutrition
ALEXANDER SILVERMAN (University of Pittsburgh), Geophysics
JOEL STEBBINS (University of Wisconsin), Astronomy
CHESTER STOCK (California Institute of Technology), Paleontology

OFFICES OF ADMINISTRATION

Office of the President

VANNEVAR BUSH, *President*
WALTER M. GILBERT, *Executive Officer*
SAMUEL CALLAWAY, *President's Secretary*

Office of Publications and Public Relations

THEODORE H. DILLON, *Director*
DOROTHY R. SWIFT, *Editor*

Office of the Bursar

EARLE B. BIESECKER, *Bursar*
J. STANLEY LINGBACH, *Assistant Bursar*

Investment Office (New York City)

DEVEREUX JOSEPHS, *Investment Officer*
PARKER MONROE, *Investment Officer*

ORGANIZATION, PLAN, AND SCOPE

The Carnegie Institution of Washington was founded by Andrew Carnegie, January 28, 1902, when he gave to a board of trustees an endowment of registered bonds of the par value of ten million dollars. To this fund an addition of two million dollars was made by Mr. Carnegie on December 10, 1907, and a further addition of ten million dollars was made by him on January 19, 1911. Furthermore, the income of a reserve fund of about three million dollars, accumulated in accordance with the founder's specifications in 1911, is now available for general use and a sum of five million dollars has been paid by the Carnegie Corporation of New York as an increase to the Endowment Fund of the Institution, payments having been completed in 1931. The Institution was originally organized under the laws of the District of Columbia and incorporated as the *Carnegie Institution*, articles of incorporation having been executed on January 4, 1902. The Institution was reincorporated, however, by an act of the Congress of the United States, approved April 28, 1904, under the title of the *Carnegie Institution of Washington*. (See existing Articles of Incorporation on following pages.)

Organization under the new Articles of Incorporation was effected May 18, 1904, and the Institution was placed under the control of a board of twenty-four trustees, all of whom had been members of the original corporation. The trustees meet annually in December to consider the affairs of the Institution in general, the progress of work already undertaken, and the initiation of new projects, and to make the necessary appropriations for the ensuing year. During the intervals between the meetings of the trustees the affairs of the Institution are conducted by an Executive Committee chosen by and from the Board of Trustees and acting through the President of the Institution as chief executive officer.

The Articles of Incorporation of the Institution declare in general "that the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind."

The Institution is essentially an operating organization. It attempts to advance fundamental research in fields not normally covered by the activities of other agencies, and to concentrate its attention upon specific problems, with the idea of shifting attack from time to time to meet the more pressing needs of research as they develop with increase of knowledge. Some of these problems require the collaboration of several investigators, special equipment, and continuous effort. Many close relations exist among activities of the Institution, and a type of organization representing investigations in astronomy, in terrestrial sciences, in biological sciences, and in historical research has been effected. Conference groups on various subjects have played a part in bringing new vision and new methods to bear upon many problems. Constant efforts are made to facilitate interpretation and application of results of research activities of the Institution, and an Office of Publications provides means for appropriate publication.

ARTICLES OF INCORPORATION

PUBLIC No. 260. An Act to incorporate the Carnegie Institution of Washington.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the persons following being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

SEC. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings, and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

SEC. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, *Samuel P. Langley*, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, *Ethan A. Hitchcock*, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership

to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold, and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time to hold as investments the securities hereinafter referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corporation hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia,

January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books, or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

SEC. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

SEC. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

SEC. 9. That this Act shall take effect immediately.

Approved, April 28, 1904

BY-LAWS OF THE INSTITUTION

Adopted December 13, 1904. Amended December 13, 1910, December 13, 1912, December 10, 1937, December 15, 1939, December 13, 1940, and December 18, 1942

ARTICLE I

THE TRUSTEES

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members. The Trustees shall hold office continuously and not for a stated term.
2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.
3. No Trustee shall receive any compensation for his services as such.
4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

ARTICLE II

MEETINGS

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year unless the date and place of meeting are otherwise ordered by the Executive Committee.
2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.
3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

ARTICLE III

OFFICERS OF THE BOARD

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.
2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

CARNEGIE INSTITUTION OF WASHINGTON

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties.

ARTICLE IV

EXECUTIVE ADMINISTRATION

The President

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall sign and execute on behalf of the corporation all contracts and instruments necessary in authorized administrative and research matters and affix the corporate seal thereto when necessary, and may delegate the performance of such acts and other administrative duties in his absence to the Executive Officer. He may execute all other contracts, deeds, and instruments on behalf of the corporation and affix the seal thereto when expressly authorized by the Board of Trustees or Executive Committee. He may, within the limits of his own authorization, delegate to the Executive Officer authority to act as custodian of and affix the corporate seal. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

4. There shall be an officer designated Executive Officer who shall be appointed by and hold office at the pleasure of the President, subject to the approval of the Executive Committee. His duties shall be to assist and act for the President as the latter may duly authorize and direct.

BY-LAWS OF THE INSTITUTION

5. The President shall retire from office at the end of the calendar year in which he becomes sixty-five years of age.

ARTICLE V COMMITTEES

1. There shall be the following standing Committees, *viz.* an Executive Committee, a Finance Committee, and an Auditing Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio* and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication. The Executive Committee shall have power to authorize the purchase, sale, exchange, or transfer of real estate.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of five members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and invested funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees. It shall have power to authorize the purchase, sale, exchange, or transfer of securities and to delegate this power. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. The Auditing Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

8. The Auditing Committee shall, before each annual meeting of the Board of Trustees, examine the accounts of business transacted under the Finance Committee and the Executive Committee. They may avail themselves at will of the services and examination of the Auditor appointed by the Board of Trustees. They shall report to the Board upon the collection of moneys to which the Institution is entitled, upon the investment and reinvestment of principal, upon the conformity of expen-

CARNEGIE INSTITUTION OF WASHINGTON

ditures to appropriations, and upon the system of bookkeeping, the sufficiency of the accounts, and the safety and economy of the business methods and safeguards employed.

9. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting. In case of vacancy in the Finance Committee or the Auditing Committee, upon request of the remaining members of such committee, the Executive Committee may fill such vacancy by appointment until the next meeting of the Board of Trustees.

10. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

ARTICLE VI

FINANCIAL ADMINISTRATION

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees, or as provided in Article V, paragraph 6, hereof.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures of the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property, and funds invested and to be invested, shall be deposited in such safe depository or in the custody of such trust company and under such safeguards as the Trustees and Finance Committee shall designate; and the income available for expenditure of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

6. Any trust company entrusted with the custody of securities by the Finance Committee may, by resolution of the Board of Trustees, be made Fiscal Agent of the Institution, upon an agreed compensation, for the transaction of the business coming within the authority of the Finance Committee.

ARTICLE VII

AMENDMENT OF BY-LAWS

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

ABSTRACT OF MINUTES OF THE FORTY-FOURTH MEETING OF
THE BOARD OF TRUSTEES

The meeting was held in New York in the Board Room of the Carnegie Corporation of New York on Friday, December 18, 1942. It was called to order at 11:00 A.M. by the Chairman, Mr. Forbes.

Upon roll call, the following Trustees responded: Thomas Barbour, James F. Bell, Robert Woods Bliss, Lindsay Bradford, Frederic A. Delano, Homer L. Ferguson, W. Cameron Forbes, Walter S. Gifford, Herbert Hoover, Walter A. Jessup, Frank B. Jewett, Alfred L. Loomis, Roswell Miller, Seeley G. Mudd, Henry R. Shepley, Richard P. Strong, Frederic C. Walcott, and Lewis H. Weed. The President of the Institution, Dr. Vannevar Bush, was also in attendance.

The minutes of the forty-third meeting were approved as printed and submitted to the members of the Board.

Reports of the President, the Executive Committee, the Auditor, the Finance Committee, the Auditing Committee, and of Chairmen of Divisions, Directors of Departments, and Research Associates of the Institution were presented and considered.

The following appropriations for the year 1943 were authorized:

Pension Fund	\$ 60,000
Administration (including Investment Office and Insurance) ..	130,580
Publications (including Office of Publications and Public Relations)	22,380
Departmental Research Operations.....	954,270
	<hr/>
	\$1,167,230

The Chairman reported the death of Stewart Paton. As a result of balloting Henning W. Prentis, Jr., President of the Armstrong Cork Company, Lancaster, Pennsylvania, was elected to fill the existing vacancy in the Board.

Mr. Forbes was re-elected Chairman of the Board, Mr. Gifford was re-elected Vice-Chairman, and Mr. Delano was re-elected Secretary, each for the ensuing period of three years.

Walter A. Jessup, Henry R. Shepley, and Lewis H. Weed were re-elected members of the Executive Committee for a period of three years.

Walter S. Gifford, Elihu Root, Jr., and Frederic C. Walcott were re-elected members of the Finance Committee for a period of three years.

Frederic A. Delano was re-elected Chairman of the Auditing Committee for a period of three years, and Homer L. Ferguson and James W. Wadsworth were re-elected members of this Committee for the same period.

CARNEGIE INSTITUTION OF WASHINGTON

Upon recommendation of the Executive Committee, article 2, section 1 of the By-Laws of the Institution was amended to read as follows:

“The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year unless the date and place of meeting are otherwise ordered by the Executive Committee.”

The meeting adjourned at 12:50 P.M., whereupon members journeyed to luncheon, upon invitation of Mrs. Carnegie, at her home.

REPORT OF THE EXECUTIVE COMMITTEE

FOR THE YEAR ENDING OCTOBER 31, 1942

To the Trustees of the Carnegie Institution of Washington:

GENTLEMEN: Article V, section 3 of the By-Laws provides that the Executive Committee shall submit, at the annual meeting of the Board of Trustees, a report for publication; and Article VI, section 3 provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for the fiscal year ending October 31, 1942.

During this year the Executive Committee held five meetings, printed reports of which have been mailed to each Trustee and constitute a part of this report.

A statement of activities of the Institution is contained in the report of the President, which has been considered and approved by the Executive Committee, and is submitted herewith. The Executive Committee is gratified at the extent to which the government has called upon the Institution for cooperation in war research, including administrative services by the President and technical services by the scientific staff. Such contributions serve a national purpose and tend also to expand the Institution's scope of usefulness in its normal sphere. The detailed estimate of expenditures for the succeeding year contained in the report of the President has been considered by the Executive Committee, which has approved the recommendations of the President in respect thereto and has provisionally approved the budget estimates based thereon and submitted therewith. Close attention has been given both by the Executive Committee and by the Finance Committee to the question of availability of funds for Institution activities in 1943, and budget recommendations are based upon the judgment of these Committees with respect to financial policy during the present national emergency.

The Board of Trustees, at its meeting of December 12, 1941, appointed Arthur Young and Company to audit the accounts of the Institution for the fiscal year ending October 31, 1942. The report of the Auditor, including a balance sheet showing assets and liabilities of the Institution on October 31, 1942, is submitted as a part of the report of the Executive Committee.

In addition to the report of the Auditor there is also submitted a financial statement for the fiscal year ending October 31, 1942, showing funds available for expenditures and amounts allotted by the Executive Committee, a customary statement of receipts and disbursements since the organization of the Institution on January 28, 1902, and a schedule of real estate and equipment at original cost. These statements together with the tables in the Auditor's report comprise a full statement of the finances of the Institution.

A vacancy exists in the membership of the Board of Trustees by reason of the death of Stewart Paton on January 7, 1942.

Tenure of office of the following officers of the Board of Trustees will expire at the annual meeting in December: Mr. Forbes, Chairman of the Board; Mr. Gifford,

Vice-Chairman of the Board; and Mr. Delano, Secretary of the Board. Tenure of office of Messrs. Jessup, Shepley, and Weed as members of the Executive Committee, of Messrs. Gifford, Root, and Walcott as members of the Finance Committee, and of Messrs. Bliss, Delano, and Wadsworth as members of the Auditing Committee will also expire at the annual meeting.

W. CAMERON FORBES, *Chairman*
VANNEVAR BUSH
FREDERIC A. DELANO
WALTER S. GIFFORD
WALTER A. JESSUP
HENRY R. SHEPLEY
FREDERIC C. WALCOTT
LEWIS H. WEED

November 6, 1942

FINANCIAL STATEMENT FOR FISCAL YEAR ENDING OCTOBER 31, 1942

	Balances unallotted Oct. 31, 1941	Trustees' appropriation Dec. 12, 1941	Revertments and transfers Nov. 1, 1941 to Oct. 31, 1942	Total available 1942	Executive Committee allotments 1942	Transfers by Executive Committee	Unallotted balances Oct. 31, 1942
Departmental Research Operations:							
Embryology.....		\$78,505	.....	\$78,505.00	\$78,505.00	.....	.....
Genetics.....		124,000	\$2,500.00	126,500.00	126,500.00	.....	.....
Nutrition Laboratory.....		18,700	.....	18,700.00	18,700.00	.....	.....
Geophysical Laboratory.....		159,832	.....	159,832.00	159,832.00	.....	.....
Historical Research.....		130,583	.....	130,583.00	130,583.00	.....	.....
Mount Wilson Observatory.....		209,815	.....	209,815.00	209,815.00	.....	.....
Plant Biology.....		59,970	.....	59,970.00	59,970.00	.....	.....
Terrestrial Magnetism.....		221,480	.....	221,480.00	221,480.00	.....	.....
Research Projects of Limited Tenure.....		60,000	.....	62,155.07	58,560.00	.....	\$3,595.07
Publications.....		52,120	2,047.26	129,036.26	63,137.96	.....	65,898.30
Administration.....		117,520	.....600.00	118,120.00	118,120.00	.....	.....
Pension Fund.....		60,000	.....	60,000.00	60,000.00	.....	.....
General Contingent Fund.....		10,000	73,101.42	176,110.18	9,864.62	\$3,100.00	163,145.56
Carnegie Corporation Emergency Fund		.....	152,191.36	256,816.36	82,360.00	.....	174,456.36
	\$274,657.83	\$1,302,525	\$230,440.04	\$1,807,622.87	\$1,397,427.58	\$3,100.00	\$407,095.29

AGGREGATE CASH RECEIPTS AND DISBURSEMENTS FROM ORGANIZATION, JANUARY 28, 1902, TO OCTOBER 31, 1942

RECEIPTS	DISBURSEMENTS
<i>Securities Sold or Redeemed</i>	<i>Securities Purchased</i>.....\$90,364,749.74
<i>Interest from Securities and Bank Balances</i>	<i>Accrued Interest on Securities, Purchased</i>.....693,133.95
<i>Sales of Publications</i>	<i>Pension Fund</i>.....1,299,394.76
<i>Colburn Estate (Bequest)</i>	<i>General Reserve Fund</i>.....29,827.88
<i>Harriman Fund (Sale of Land)</i>	<i>Insurance Fund</i>.....140,532.24
<i>Teepie Estate (Bequest)</i>	<i>Harriman Fund</i>.....79.98
<i>Carnegie Corporation of New York (Endowment Increase and for Specific Purposes)</i>	<i>Special Emergency Reserve Fund</i>.....63,819.41
<i>From Other Organizations and Individuals for Specific Purposes</i>	<i>National Defense Revolving Fund</i>.....690,700.00
<i>Pension Fund (Refunds)</i>	<i>General Contingent Fund</i>.....272,770.00
<i>General Reserve Fund (Refunds)</i>	<i>Carnegie Corporation of New York Emergency Fund</i>.....45,558.64
<i>Insurance Fund (Refunds)</i>	<i>Administration Building and Addition:</i>
<i>National Defense Revolving Fund (Refunds)</i>	<i>Construction and Site (Old Building)</i>.....309,915.69
<i>Administration Building Addition Account, Rentals and Refunds</i>	<i>Construction (Addition to Administration Bldg.)</i>.....416,206.07
<i>Miscellaneous Refunds and Receipts</i>	<i>Site (Addition to Administration Building)</i>.....68,570.96
	<i>Miscellaneous Expenditures*</i>40,825.37
	<i>Departmental Research Operations:</i>
	<i>Departments of Research, Buildings and Equipment</i>.....3,884,549.19
	<i>Departmental Operations</i>.....31,277,680.51
	<i>Research Projects of Limited Tenure</i>.....5,401,079.61
	<i>Publication</i>.....2,828,687.15
	<i>Administration</i>.....2,562,170.05
	<i>National Research Council</i>.....150,000.00
	<i>Miscellaneous</i>.....9,008.82
	<i>October 31, 1942, Cash in Banks</i>.....\$140,549,260.02
	<i></i>742,682.29
	<i></i>\$141,291,942.31

* Includes Equipment \$7,206.41, Repairs and Alterations to Old Building \$18,599.29.

REAL ESTATE AND EQUIPMENT, ORIGINAL COST

Administration (October 31, 1942)

Washington, D. C.

Building, site, and equipment		\$848,927.91
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Division of Plant Biology (September 30, 1942)

Stanford University, California (Headquarters)

Buildings and grounds	\$74,423.46	
Laboratory	38,655.20	
Library	25,585.21	
Operating equipment	13,901.82	152,565.69

Department of Embryology (September 30, 1942)

Wolfe and Madison Streets, Baltimore, Maryland

Library	\$4,038.76	
Laboratory	18,726.82	
Administration	7,919.09	30,684.67

Department of Genetics (September 30, 1942)

Cold Spring Harbor, Long Island, New York

Buildings, grounds, field	\$289,989.35	
Operating equipment	33,591.88	
Laboratory apparatus	36,606.37	
Library	51,259.32	
Archives	45,488.90	456,935.82

Geophysical Laboratory (September 30, 1942)

2801 Upton Street N.W., Washington, D. C.

Building, library, operating appliances	\$290,626.05	
Laboratory apparatus	171,304.96	
Shop equipment	21,103.00	483,034.01

Division of Historical Research (September 30, 1942)

Administration Building, Washington, D. C.

Operating equipment	\$31,953.69	
Library	10,809.62	42,763.31

Nutrition Laboratory (September 30, 1942)

29 Vila Street, Boston, Massachusetts

Building, office, shop, and library	\$134,258.06	
Laboratory apparatus	32,669.28	166,927.34

Mount Wilson Observatory (September 30, 1942)

Pasadena, California

Buildings and grounds	\$222,458.33	
Shop equipment	47,255.77	
Instruments	684,986.05	
Furniture and operating appliances	147,148.26	
Hooker 100-inch reflector	638,507.51	1,740,355.92

Department of Terrestrial Magnetism (September 30, 1942)

5241 Broad Branch Road N.W., Washington, D. C.

Building, site, and office	\$253,369.45	
Survey equipment	93,475.51	
Instruments, laboratory, and shop equipment	464,437.47	811,282.43

\$4,733,477.10

REPORT OF AUDITORS

*To the Board of Trustees
Carnegie Institution of Washington
Washington, D. C.*

We have made an examination of the books and accounts of CARNEGIE INSTITUTION OF WASHINGTON for the year ended October 31, 1942.

Income from investments and other sources has been duly accounted for and all disbursements were evidenced by paid voucher checks and/or properly approved invoices. The cash and securities were verified by certificates received from depositories and custodians. As in past years, the detail accounts of the Departments of Research in the field have been audited by the Bursar of the Institution, and we are of the opinion, as a result of reviewing the internal audit methods in force, that such internal audit is satisfactorily conducted.

The securities are stated at cost, amortized cost, or value at date acquired, this being the established custom of the Institution. In accordance with a recommendation made in February 1940 by the Institution's Finance Committee, all premiums on all obligations purchased subsequent to January 1, 1940 are being amortized on a straight-line basis to the date on which an obligation is first callable or payable at par. The amortization of the premiums applicable to the year ended October 31, 1942 amounted to \$15,694.46 and has been deducted from the cost of such obligations.

Real estate and equipment are stated at original cost and books on hand for sale at their sales prices. No provision has been made for depreciation of property owned by the Institution.

We inspected certified copies of the minutes of the meetings of the Board of Trustees and Executive Committee as authority for the appropriations and allotments made during the year.

In our opinion, on the basis of valuations stated above, the accompanying balance sheet, statement of receipts and disbursements, and detailed schedule of securities properly present the financial position of Carnegie Institution of Washington at October 31, 1942 and the transactions for the year ended that date.

ARTHUR YOUNG & COMPANY
Accountants and Auditors

*New York, N. Y.
November 25, 1942*

BALANCE SHEET OCTOBER 31, 1942

ASSETS		LIABILITIES	
<i>Investments</i>			
Securities.....	\$31,861,866.97	<i>Endowment and Other Funds</i>	
Cash:		<i>Capital Funds</i>	
Awaiting investment.....	126,052.07	Endowment Fund.....	\$27,000,000.00
Reserved for current needs	34,280.21	Colburn Fund.....	103,310.80
		Capital Reserve Fund.....	3,315,390.72
	\$32,022,199.25	Harriman Fund (\$179,628.05 included in Property Fund below).....	327,428.56
		Teuple Fund.....	5,160.62
			\$30,751,290.70
<i>Property Account</i>		<i>Special Funds</i>	
Real Estate and Equipment at original cost:		General Reserve Fund.....	830,346.55
Office of Administration.....	\$848,927.91	Pension Fund.....	280,562.00
Departments of Research.....	3,884,549.19	Current Funds Invested.....	160,000.00
			\$32,022,199.25
		<i>Property Fund</i>	
		Income Invested.....	\$4,553,849.05
		Harriman Property (Gift).....	179,628.05
			4,733,477.10
<i>General Fund</i>		<i>General Fund</i>	
Cash:		Current Obligations:	
Income account.....	\$582,350.01	Departmental Research Operations.....	\$345,394.27
Petty cash and stamps.....	500.00	Research Projects of Limited Tenure.....	48,988.31
	\$582,850.01	Publications.....	106,824.40
		Administration.....	31,183.53
		General Contingent Fund.....	172,448.18
		Carnegie Corporation	189,906.36
		Emergency Fund.....	
		National Defense Revolving Fund (includes reimbursable expenditures of \$150,767.84 carried in accounts receivable, per contra).....	300,000.00
			\$1,194,745.05
			5,604.29
		Unappropriated Fund.....	\$1,200,349.34
		Less: Current Funds Invested (see above).....	160,000.00
			\$1,040,349.34
		Value of Publications and Invoices.....	181,689.43
		Publication Paper and Supplies in Stock.....	2,781.20
			\$37,980,496.32

RECEIPTS AND DISBURSEMENTS FOR THE YEAR ENDED OCTOBER 31, 1942

RECEIPTS		DISBURSEMENTS	
Securities Redeemed or Sold.....	\$4,063,050.48	Securities Purchased.....	\$4,331,733.47
Interest and Dividends from Securities.....	1,289,531.04	Accrued Interest on Securities Purchased.....	6,987.40
Sales of Publications.....	3,516.32	Pension Fund.....	97,951.76
Refunds and Other Credits.....	90,174.44	General Reserve Fund.....	29,827.88
From Other Organizations and Individuals for Specific Purposes:		General Contingent Fund.....	10,861.95
Carnegie Corporation of New York.....	160,000.00	Carnegie Corporation Emergency Fund.....	12,750.00
National Research Council.....	1,200.00	Harriman Fund.....	41.53
California Institute of Technology.....	4,999.92	Departmental Research Operations*.....	1,087,251.92
Rockefeller Foundation.....	9,000.00	Research Projects of Limited Tenure.....	57,978.74
Pension Fund (Refunds).....	1,475.00	General Publication.....	25,412.06
General Reserve Fund (Refunds).....	177.38	Office of Publications.....	21,135.95
National Defense Revolving Fund (Refunds).....	630,977.51	Administration.....	116,091.56
	\$6,254,102.09	National Defense Revolving Fund.....	690,700.00
		Cash in Banks, October 31, 1942:	\$6,488,724.22
		Uninvested principal:	
		Awaiting investment.....	\$126,052.07
		Reserved for current needs.....	34,280.21
			<hr/>
		Income Account.....	\$160,332.28
			<hr/>
			582,350.01
Cash in Banks, November 1, 1941.....	977,304.42		
	\$7,231,406.51		
			\$7,231,406.51

*Includes specific terminating projects administered through departments.

SCHEDULE ON SECURITIES

Aggregate par or nominal value	Description	Ma- turity	Cost, amortized cost, or value at date acquired
UNITED STATES GOVERNMENT BONDS			
\$300,000	U. S. Guar. Federal Farm Mtg. Corp. 3s.	1949-44	\$309,210.93*
120,000	U. S. Guar. Reconstruction Finance Corp. Notes, 1s.	1944	120,000.00
460,000	U. S. of America Treasury Notes 1½s.	1946	462,084.38
575,000	U. S. of America Treasury 2s.	1950-48	579,002.95*
304,000	U. S. of America Treasury 2s.	1951-49	304,000.00
312,000	U. S. of America Treasury 2s.	1951-49	312,000.00
200,000	U. S. of America Treasury 2s.	1952-50	200,000.00
800,000	U. S. of America Treasury 2½s.	1955-52	800,000.00
1,239,000	U. S. of America Treasury 2½s.	1954-52	1,245,487.46*
300,000	U. S. of America Treasury 2½s.	1958-56	300,000.00
350,000	U. S. of America Treasury 2½s.	1967-62	350,000.00
50,000	U. S. of America Savings Defense "G" 2½s.	1953	50,000.00
50,000	U. S. of America Savings Defense "G" 2½s.	1954	50,000.00
50,000	U. S. of America Savings Defense "G" 2½s.	1954	50,000.00
\$5,110,000	Total United States Government		\$5,131,785.72
FOREIGN BONDS			
\$55,000	Canada, Dom. of 5s.	1952	\$60,450.00
90,000	Canadian National Ry. Co. 4½s Guar.	1951	90,329.34*
100,000	Canadian National Ry. Co. 4½s Guar.	1957	112,000.00
100,000	Canadian National Ry. Co. 5s Guar.	1969	98,500.00
57,000	Canadian National Ry. Co. 5s Guar.	1969	62,344.44*
35,000	Canadian National Ry. Co. 5s Guar.	1970	38,119.77*
91,000	Canadian Pacific Ry. Co. Coll. Tr. 5s.	1954	90,835.11
100,000	Province of Alberta Deb. 4½s.	1958	93,750.00
100,000	Province of Alberta Deb. 5s.	1950	101,150.00
150,000	Province of Manitoba Deb. 4½s.	1958	142,886.77
100,000	Province of Nova Scotia Deb. 4½s.	1952	100,312.50
40,000	Province of Ontario Deb. 6s.	1943	43,137.50
250,000	Shawinigan Water and Power Co. 1st Mtg. & Coll. Tr. S. F. 4½s.	1967	238,510.42
100,000	City of Toronto Cons. Loan Deb. 5s.	1949	96,164.59
\$1,368,000	Total Foreign		\$1,368,490.44
PUBLIC UTILITY BONDS			
\$93,000	American Gas & Electric Co. S. F. Deb. 2½s.	1950	\$94,627.50*
300,000	Arkansas Power & Light Co. 1st & Ref. Mtg. 5s.	1956	292,312.50
75,000	Blackstone Valley Gas & Electric Co. Mtg. & Coll. Tr. 4s.	1965	76,875.00
249,000	Columbus & Southern Ohio Electric Co. 1st Mtg. 3½s.	1970	267,440.95*
23,900	Commonwealth Edison Co. Conv. Deb. 3½s.	1958	23,910.75
83,000	Commonwealth Edison Co. 1st Mtg. 3½s.	1968	85,712.87
50,000	Consolidated Edison Co. of N. Y. Deb. 3½s.	1948	50,875.00
40,000	Consolidated Edison Co. of N. Y. Deb. 3½s.	1958	40,730.00
100,000	Detroit Edison Co. Gen. & Ref. Mtg. 4s.	1965	103,500.00
200,000	Gulf States Util. Co. 1st Mtg. & Ref. 3½s.	1969	213,500.00
25,000	Houston Lighting & Power Co. 1st Mtg. 3½s.	1966	25,750.00
200,000	Illinois Power & Light Corp. 1st & Ref. Mtg. 5s.	1956	196,750.00
150,000	Louisiana Power & Light Co., 1st Mtg. 5s.	1957	154,900.00
100,000	Metropolitan Edison Co. 1st Mtg. 4½s.	1968	109,470.00
100,000	Minnesota Power & Light Co. 1st & Ref. Mtg. 4½s.	1978	92,156.25
50,000	Monongahela West Penn Pub. Serv. Co. 1st Mtg. 4½s.	1960	52,000.00
98,000	Montana Power Co., 1st & Ref. Mtg. 3½s.	1966	98,980.00
100,000	New Orleans Public Service Co. 1st & Ref. Mtg. 5s.	1955	99,200.00
65,000	New York & Westchester Lighting Co., Deb. 5s.	1954	67,052.50
57,000	North American Co., Deb. 3½s.	1949	58,122.50
50,000	Northern States Power Co., 1st & Ref. Mtg. 3½s.	1967	47,500.00
100,000	Ohio Edison Co. 1st Mtg. 4s.	1967	100,266.25
100,000	Ohio Power Co. 1st Mtg. 3½s.	1968	101,500.00
100,000	Ohio Public Service Co., 1st Mtg. 4s.	1962	102,625.00
200,000	Ohlahaoma Gas & Electric Co., 1st Mtg. 3½s.	1966	205,000.00
97,000	Oklahoma Natural Gas Co., 1st Mtg. 3½s.	1955	104,507.80
100,000	Pacific Gas & Electric Co., 1st & Ref. Mtg. 3½s.	1961	102,500.00
100,000	Pacific Gas & Electric Co., 1st & Ref. Mtg. 4s.	1964	104,000.00
141,000	Public Service Co., of No. Ill., 1st Mtg. 3½s.	1968	145,230.00
60,000	Puget Sound Power & Light Co., 1st & Ref. Mtg. 4½s.	1950	56,550.00
50,000	Puget Sound Power & Light Co., 1st & Ref. Mtg. 5½s.	1949	31,900.00
300,000	Southern California Edison Co., Ltd. 1st & Ref. Mtg. 3s.	1965	313,970.20*
150,000	Southern Natural Gas Co., 1st Mtg. Pipe Line, S. F. 3½s.	1956	154,112.94*
300,000	Texas Electric Service Co., 1st Mtg. 5s.	1960	292,700.00
195,500	Texas Power & Light Co., 1st & Ref. Mtg. 5s.	1956	200,528.02
120,000	Toledo Edison Co., 1st Mtg. 3½s.	1968	121,800.00
263,000	Virginia Electric & Power Co., 1st & Ref. Mtg. 3½s.	1968	272,205.00
225,000	Wisconsin Electric Power Co., 1st Mtg. 3½s.	1968	232,875.00
\$4,810,400	Total Public Utility		\$4,893,636.03

*After deduction for amortization of premiums on bonds purchased subsequent to January 1, 1940. Amortization is on a straight-line basis to the date on which bonds are first callable or payable at par.

SCHEDULE OF SECURITIES—Continued

Aggregate par or nominal value	Description	Ma- turity	Cost, amortized cost, or value at date acquired
COMMUNICATION BONDS			
\$280,000	American Telephone & Telegraph Co., Conv. Deb. 3s.....	1956	\$307,703.79*
51,000	American Telephone & Telegraph Co., Deb. 3 ¼s.....	1961	51,510.00
314,000	American Telephone & Telegraph Co., Deb. 3 ¼s.....	1966	326,706.75
25,000	Mountain States Telephone & Telegraph Co., Deb. 3 ¼s.....	1968	25,500.00
52,000	New England Telephone & Telegraph Co., 1st Mtg. 5s.....	1952	51,748.00
75,000	Southern Bell Telephone & Telegraph Co., Deb. 3 ¼s.....	1962	72,375.00
\$797,000	Total Communications.....	.....	\$835,543.54
RAILROAD EQUIPMENT TRUSTS			
\$50,000	Erie R. R. Co., 4 ½s Guar.....	1943	\$47,960.26
88,000	Illinois Central R. R. Co., 4 ½s.....	1943-44	84,397.19
82,000	Pennsylvania R. R. Co. 2 ¾s.....	1956	81,283.64
\$220,000	Total Railroad Equipment Trusts.....	.....	\$213,641.09
RAILROAD BONDS			
\$200,000	Atchison, Topeka & Santa Fe Ry. Co., 1st & Ref. Mtg. 4 ½s.....	1962	\$199,500.00
50,000	Central Pacific Ry. Co., 1st Ref. Mtg. 4s Guar.....	1949	48,250.00
100,000	Chesapeake & Ohio Ry. Co., Gen. Mtg. 4 ½s.....	1992	99,464.29
75,000	Chicago & W. Indiana R. R. Co., Cons. 4s.....	1952	70,357.66
50,000	Great Northern Ry. Co., 1st & Ref. Mtg. 4 ¼s Std.....	1961	50,113.59
100,000	Great Northern Ry. Co., Gen. Mtg. 5s.....	1973	104,385.84
150,000	Louisville & Nashville R. R. Co., 1st & Ref. Mtg. 4 ½s.....	2003	149,475.00
50,000	Oregon Short Line R. R. Co., Cons. 1st Mtg. 5s.....	1946	48,405.15
75,000	Pennsylvania R. R. Co., Gen. Mtg. 4 ½s.....	1965	75,918.75
100,000	Pennsylvania R. R. Co., Cons. Mtg. 4 ½s.....	1960	104,662.50
50,000	Pittsburgh, Cin. Chi. & St. L. R. R. Co., Gen. Mtg. 5s Guar.....	1975	51,898.98
100,000	Southern Rwy. Co., 1st Cons. Mtg. 5s.....	1994	103,580.34
70,000	Terminal R. R. Assn. of St. Louis S. F. Gen. Ref. Mtg. 4s.....	1953	63,603.92
100,000	Toledo & Ohio Central Ry. Co., Ref. & Imp. Mtg. 3 ¼s Guar.....	1960	99,000.00
200,000	Union Pacific R. R. Co., 1st Mtg. R. R. & Land Grant 4s.....	1947	218,942.61
2,084,000	Union R. R. Co., Deb. 6s Guar.....	1946	2,084,000.00
100,000	Virginian Ry. Co., 1st Lien & Ref. Mtg. 3 ¾s.....	1966	102,250.00
100,000	West Shore R. R. Co., 1st Mtg. 4s Guar.....	2361	78,140.00
50,000	Western Maryland Ry. Co., 1st & Ref. Mtg. 5 ½s.....	1977	42,677.19
\$3,804,000	Total Railroad.....	.....	\$3,794,625.82
INDUSTRIAL AND MISCELLANEOUS BONDS			
\$21,000	Allis-Chalmers Mfg. Co., Conv. S. F. Deb. 4s.....	1952	\$21,666.54
100,000	Atlantic Refining Co., Deb. 3s.....	1953	103,521.97*
150,000	Bethlehem Steel Corp., Conv. S. F. Deb. 3 ½s.....	1952	148,750.00
4,000	Phelps Dodge Corp. Conv. Deb. 3 ¼s.....	1952	4,000.00
125,000	Railway Express Agency, Serial Notes 1 ½s-2 ½s.....	1942-48	125,000.00
98,000	Republic Steel Corp. Gen. Mtg. 4 ½s.....	1956	101,865.37*
97,500	Republic Steel Corp. Gen. Mtg. 4 ½s.....	1961	100,770.21*
86,000	Scovill Manufacturing Co., Deb. 3 ¼s.....	1950	87,337.78*
400,000	Shell Union Oil Corp., Deb. 2 ½s.....	1954	384,176.25
300,000	Socony-Vacuum Oil Co. Deb. 2 ½s.....	1955	312,990.20*
75,000	Socony-Vacuum Oil Co., Deb. 3s.....	1964	78,000.00
150,000	Standard Oil Co. of Calif. Deb. 2 ¾s.....	1966	153,593.75*
200,000	Standard Oil Co., of N. J. Deb. 2 ¾s.....	1953	203,891.89*
1,925,000	Tennessee Coal Iron & R. R. Co., Gen. Mtg. 5s (Payment Guar. by U. S. Steel Corp.).....	1951	1,925,000.00
230,000	Westinghouse Electric & Mfg. Co., Deb. 2 ½s.....	1951	233,258.33*
148,000	West Virginia Pulp & Paper Co., 1st Mtg. 3s.....	1954	146,520.00
\$4,109,500	Total Industrial and Miscellaneous.....	.....	\$4,130,342.29
MORTGAGES			
\$96,710.44	Lawyers Mtg. Co., Guaranteed 1st Mtg. Ctfs., Series 18397T 4 ½%....	1944	\$95,602.34
100,000	Lawyers Mtg. Co., Guaranteed 1st Mtg. Ctfs. 4 ¼% No. 29940T....	1940	98,022.20
80,000	Lawyers Title and Guar. Co., 5 ½% Mtg. Par Ctfs. No. D 424421381...	1935	79,829.60
90,000	N. Y. Title and Mtg. Co., Guaranteed 1st Mtg. Ctfs., 5 ½% No. N97...	1938	90,000.00
93,750	N. Y. Title and Mtg. Co., Guaranteed 1st Mtg. Ctfs., 4 ½% No. N86...	1940	93,750.00
90,000	Participating Ctf. in Consol. Bond and Mtg., S. E. corner Madison Ave. and 40th St., Manhattan, 4%.....	1944	90,000.00
\$550,460.44	Total Mortgages.....	.....	\$547,204.14
\$20,769,360.44	BONDS AND MORTGAGES—Funds Invested.....	.....	\$20,915,269.07

* After deduction for amortization of premiums on bonds purchased subsequent to January 1, 1940. Amortization is on a straight-line basis to the date on which bonds are first callable or payable at par.

SCHEDULE OF SECURITIES—Continued

Number of shares	Description	Cost, amortized cost, or value at date acquired
PREFERRED STOCKS		
100	American Brake Shoe and Foundry Co., 5¼% Cum. Pref.....	\$12,653.50
2,010	American Cyanamid Co., 5% Cum. Pref.....	22,471.25
1,500	Appalachian Electric Power Co., 4½% Cum. Pref.....	159,000.00
1,500	Bethlehem Steel Corp. 7% Cum. Pref.....	183,637.50
500	J. I. Case Thresh. Machine Co., 7% Cum. Pref.....	62,225.00
600	Cleveland Electric Illuminating Co., \$4.50 Cum. Pref.....	68,112.25
1,000	Deere & Company, 7% Cum. Pref.....	28,812.50
1,125	E. I. Du Pont de Nemours & Co., \$4.50 Cum. Pref.....	116,125.00
1,500	General Motors Corp. \$5.00 Cum. Pref.....	187,937.50
225	Grant Co. (W. T.) 5% Cum. Pref.....	7,642.76
530	Johns-Manville Corp. 7% Cum. Pref.....	67,294.52
5,000	S. H. Kress Co., 6% Cum. Spl. Pref.....	58,269.00
1,000	New York State Electric & Gas Corp. 5.10% Cum. Pref.....	103,250.00
1,000	Northern States Power Co., \$5.00 Cum. Pref.....	103,000.00
770	Ohio Oil Co., 6% Cum. Pref.....	84,263.30
550	Ohio Power Co., 4½% Cum. Pref.....	59,925.00
550	Oklahoma Natural Gas Co., \$5.50 Cum. Conv. Prior Pref.....	62,142.51
600	Public Service Co., of Oklahoma 5% Cum. Pref.....	60,900.00
1,154	Sherwin-Williams Co., 5% Cum. Pref.....	127,190.29
1,000	Southwestern Gas & Electric Co., 5% Cum. Pref.....	110,350.00
1,000	Standard Oil Co. of Ohio 5% Cum. Pref.....	109,385.47
3,100	U. S. Steel Corp., 7% Cum. Pref.....	443,407.57
26,314	Total Preferred Stocks.....	\$2,237,994.92
COMMON STOCKS		
1,800	Air Reduction Company.....	\$107,905.16
2,000	American Brake Shoe and Foundry Co.....	87,580.95
1,500	American Can Company.....	136,846.00
3,300	American Cyanamid Co. "B".....	95,812.55
4,000	American Radiator & Standard Sanitary Corp.....	73,114.91
200	American Telephone & Telegraph Co.....	21,007.50
1,600	Bethlehem Steel Corp.....	125,270.00
2,600	Caterpillar Tractor Co.....	175,811.00
1,900	Chase National Bank of N. Y.....	61,775.00
2,400	Chrysler Corporation.....	226,638.50
1,500	Commercial Credit Co.....	72,258.75
1,900	Commercial Investment Trust Corp.....	112,346.24
150	Commercial National Bank and Trust Co. of N. Y.....	26,880.00
2,700	Continental Can Co.....	118,124.50
2,408	Continental Insurance Co.....	87,913.30
5,500	Continental Oil Co. of Delaware.....	149,622.50
2,900	Deere & Company.....	57,720.36
980	Dow Chemical Co.....	117,622.28
1,150	E. I. Du Pont de Nemours & Co.....	181,861.50
1,600	Eastman Kodak Co. of N. J.....	252,428.75
35	First National Bank of N. Y.....	60,925.00
10,600	General Electric Co.....	417,371.50
2,800	General Foods Corporation.....	114,615.00
7,600	General Motors Corporation.....	390,669.00
3,600	W. T. Grant Co.....	119,318.24
440	Guaranty Trust Co. of N. Y.....	115,954.00
5,300	Gulf Oil Corp.....	196,858.50
900	Hartford Fire Insurance Co.....	69,384.68
3,800	Humble Oil & Refining Co.....	219,969.50
1,000	Ingersoll-Rand Company.....	107,083.00
920	Inland Steel Company.....	90,662.50
1,200	Insurance Company of North America.....	79,238.15
864	International Business Machines Corp.....	117,056.84
1,000	International Harvester Co.....	82,476.25
800	Johns-Manville Corp.....	76,687.15
3,000	Kennecott Copper Corp.....	129,293.38
4,500	Kresge Company (S. S.).....	104,500.00
1,100	Liggett & Myers Tobacco Co. "B".....	110,625.00
1,600	Monsanto Chemical Co.....	160,453.00
4,100	Montgomery Ward & Co.....	220,701.08
760	National Fire Insurance Co. of Hartford.....	42,942.50
5,100	National Lead Co.....	108,585.50
2,000	Newberry Co. (J. J.).....	94,190.00
2,600	New Jersey Zinc Co.....	172,294.50
3,200	Owens-Illinois Glass Co.....	197,239.00
2,900	Parke, Davis & Co.....	107,042.00
2,500	Penney Co. (J. C.).....	229,123.50
3,900	Phelps Dodge Corp.....	145,754.79
1,200	Pittsburgh Plate Glass Co.....	131,399.75
1,800	Procter & Gamble Co.....	100,795.82
900	Pullman Inc.....	43,073.18
1,200	St. Joseph Lead Co.....	54,506.57
(Continued on following page)		

SCHEDULE OF SECURITIES—*Continued*

Number of shares	Description	Cost, amortized cost, or value at date acquired
<i>COMMON STOCKS—Continued</i>		
3,100	Sears, Roebuck & Co.....	\$244,900.90
1,500	Sherwin-Williams Co.....	147,079.47
8,000	Socony-Vacuum Oil Co.....	95,645.00
4,000	Standard Oil Co., of California.....	127,044.00
2,600	Standard Oil Co. of Indiana.....	75,550.50
1,858	Standard Oil Co. of N. J.....	98,627.38
4,300	Texas Company.....	181,018.76
2,800	Timken Roller Bearing Co.....	136,062.00
3,800	Union Carbide & Carbon Corp.....	321,683.50
1,500	United Fruit Company.....	109,972.00
1,200	United States Gypsum Co.....	120,301.00
600	United States Steel Corp.....	61,573.34
2,700	Westinghouse Electric & Mfg. Co.....	289,816.50
163,265	Total Common Stocks.....	\$8,708,602.98
189,579	COMMON AND PREFERRED STOCKS—Funds Invested.....	\$10,946,597.90
	AGGREGATE INVESTMENTS (BONDS AND STOCKS).....	\$31,861,866.97

REPORT OF THE PRESIDENT
OF THE
CARNEGIE INSTITUTION OF WASHINGTON
FOR THE YEAR ENDING OCTOBER 31, 1942

REPORT OF THE PRESIDENT
OF THE
CARNEGIE INSTITUTION OF WASHINGTON

In accordance with provisions of the By-Laws of the Institution, the President has the honor to report to the Board of Trustees on research activities of the year ending October 31, 1942, on financial and administrative matters, and on services which the Institution renders to the United States Government.

At the last meeting of the Board, following declaration of war, the Trustees adopted a resolution, in accordance with which the Institution is meeting all requests from the government for scientific aid as fully as its facilities and resources will permit. It was recognized that this policy would inevitably interrupt most of the normal program of the Institution. Accompanying scientific research for war purposes there is always an increase in fundamental knowledge; but war research is primarily applied research, and of relatively short range, whereas the normal program of the Institution is broad and basic. The action of the Trustees recognized that this Institution must place war research first, and suspend its peacetime activities in order to do so. The loss, even from a long-range point of view, will not be total, for the boundaries of knowledge are incidentally being extended, even though in strange ways, and some peacetime results will follow. No compromise is being made on this basis, however, and the requests of government are being met directly by the means best adapted to produce results, by every laboratory and scientist of the Institution that can be diverted to advantage.

After Pearl Harbor this country ceased

to be an oasis in a world at war, and entered upon a period of strife and sacrifice. To the Institution there is an intensified opportunity to serve the nation in its peril, and the effort indeed calls for the sacrifice of precious things. To only a minor extent can we still hope to continue progress in paths of research toward distant cultural objectives, and by keeping the road open avoid the loss of ground already gained. Not all scientific talents are of such nature as to be immediately and directly applicable to the waging of war, and hence the transition has occurred more rapidly in some departments than in others. The utmost effort of our research, however, wherever it has been possible to divert it successfully, is directed toward placing more powerful weapons in the hands of the youth of the land, and toward devising means better to protect their health in combat, by guarding against the rigors of disease and unnatural stress. To the extent of our ability and resources, and to the full effort of our personnel as it becomes determined how they can best serve, the Institution is committed to the service of the nation at war.

When this war is over it will have been amply demonstrated that the full prosecution of the war depended in no inconsiderable degree upon the presence in this country of an extensive and vigorous system of scientific research. This nation may again lapse into a dream of security; there may again be those who will indulge in wishful thinking to ward off the rigorous realities of a world of ambitious men. But it is hardly probable, after the present ex-

perience, that the American public as a whole will ever allow the national research effort to disintegrate. Whatever may be the changes of form that are possible results of the stresses of a long war, we will certainly continue extensive scientific research in some form when peace comes. There are many kinds of valuable research, and many means of organizing for its furtherance. One very essential kind thrives best when independent groups, free of artificial constraint, compete in that pleasant contest for credit and recognition where rivalry is intense but increasingly fair and friendly, and where the entire product becomes the possession of the people as a whole.

No matter what sort of world we live in after the war, the security of science should not depend wholly on its potential contribution to the direct needs of the state. There is a more fundamental reason than this for scientific research. This reason resides in the innermost gropings of

the human mind to know and to understand, and free men everywhere and at all times have given expression, in the institutions which they have created, to this urge for knowledge. The vicissitudes of an uncertain future may alter the organizational forms by which research is conducted, but so long as free men aspire, the effort to extend the boundaries of human knowledge will continue. In this the scientists of the Institution will have a part in the years after the war, for they are able scientists and are so recognized. The Institution itself may, however, need to find support in unexpected quarters, to be able to continue strongly on its way, if the exigencies of readjustment render its normal method of continuing insufficient. On the other hand, when this war is over the service which the Institution has rendered will be known, and the benefits which it can confer in times of peace should be all the more keenly appreciated after an interval of stress.

WAR ACTIVITIES

The policy of the Institution, in carrying on war research for government, has been to contribute the use of its facilities, the services of its regular scientific staff, and its regular overhead costs of providing administrative services and the like. The Institution is reimbursed for added out-of-pocket expenses directly attributable to the research for government. In addition, the Institution has loaned the services of some of its scientific personnel, while still continuing them on the payroll. The result has been, as would be expected, that the over-all budgets of the several departments have been substantially unchanged by reason of undertaking an extensive war research program. This is the result that was desired, for it is consistent with the wish of the Trustees that the Institution should

contribute to the war effort as far as its current resources would allow. It also makes it very clear, to one who reads our financial statement, that the Institution has certainly not profited financially by the effort; indeed, it has not asked government to carry the costs of its regular research as the effort became diverted from peace to war.

Careful attention has been given to all details of handling government funds, and a special Revolving Fund for war projects has been established to cover advances required for monthly payments of salaries and expenses representing out-of-pocket costs under contracts between the Institution and the government.

A total of 48 contracts, concerning research on 23 separate projects, have been

entered into with the Navy Department, the War Department, and the Office of Scientific Research and Development, involving a total expenditure of government funds aggregating \$1,900,000. These contracts are as nearly as possible on a cost basis and without profit to the Institution.

Every activity of the Institution has felt the effect of the war emergency, either through calls for personal service or through reorganization of programs due to work for the government. In some cases leaves of absence have permitted staff members to receive salaried appointments by the government. Services of others have been made available while they retained salaried connection with the Institution, working either in our own or in government laboratories. At the present time 34 staff members are thus on leave, and 145 others are giving full time to war research in our own laboratories or are devoting part time in various capacities to service for the government. Twenty-eight members of the scientific staff are either members, technical aides, or consultants of sections of the National Defense Research Committee. Temporary employment of about 150 additions to personnel is likewise required at present to enable the In-

stitution to meet obligations of government contracts.

In addition to his duties as Director of the Office of Scientific Research and Development, the President of the Institution has been appointed by the Joint Chiefs of Staff as Chairman of a Joint Committee on New Weapons and Equipment. This Committee is a supporting body in the organization of the Chiefs of Staff, and is concerned in an advisory capacity with the broad aspects of new weapons.

The government has formally accepted donation by the Institution of space in the Administration Building for use by the Office of Scientific Research and Development, and has expressed its appreciation of this contribution. With the exception of a few offices in the old part of the building, the government now utilizes all space available for office accommodations, and with the inauguration of work at night, the cost of operation and maintenance of the building by the Institution has steadily increased. On the other hand, certain administrative expenses which have normally occurred in former years in the form of travel and costs of meetings, lectures, and exhibits have been eliminated for the duration of the war.

FINANCES

As has been evident for some years, the favorable financial situation of the Institution which existed for three decades no longer continues. Excess of income over estimates for the year 1940 was sufficient to meet a small deficit in income for the year 1941 and leave a balance to apply toward the adjustment which will be necessary in balancing the budget of 1942. For the first time, however, we expect formally to draw upon reserves at the end of this year.

The lower estimated income for the year

1943 begins to render the problem acute, for the prospective yield for next year from present securities is approximately \$160,000 less than estimated income for 1942. At the same time it has become necessary, in accordance with the general trend, to increase salaries of mechanics and others whose services are essential to maintenance of research activities undertaken in the interest of the war effort. It is possible to reduce operating expenses to some degree, but it remains essential to keep our operating units intact in many instances so that

we may continue to render full-time service to the government. On the other hand, by reason of economies we have available funds in the form of balances to carry over to meet the need for support of special Institution projects and for publication without adding to the 1943 budget for such purposes.

With these considerations in mind, the budget for next year has been set up with a view to reducing to a minimum the call which will have to be made upon funds other than current income.

It is disturbing to present, for the first time in the history of the Institution, a budget which involves even a small predicted deficit. It is true that we have ample reserves for several years of deficit operation, and it is also true that current income could be increased, so that no predicted deficit would be necessary, by simply investing less conservatively, if the added risk were genuinely warranted. But, as matters stand, there is formally a small predicted deficit for 1943.

However, the broad question of where we are headed as an Institution, from a financial standpoint, is so great that it submerges the minor question of a deficit, or a series of deficits, in the war years. Our entire income is from endowment, and we are peculiarly vulnerable to trends which adversely affect endowed institutions. Unlike the universities, we have no income from student fees. Unlike the foundations, we carry extensive continuing operations, and cannot materially cut our grants to fit our income. If the readjustment after the war further reduces endowment income, we may indeed be in severe straits.

There is still some room for retrenchment. The deficit appears, for one reason, because we carry the annual grant from Carnegie Corporation of New York in a separate account, since it is of terminating

nature, and because we still hold to the objective which was prominently in mind when that grant was made, of extending the influence and aid of the Institution over broad scientific fields which we share with others. But the downward trend of income, from \$1,695,900 in 1936 to an estimated income of \$1,175,000 for 1943, if it continues, will soon cause us to retrench until only the regular operation of our departments remains, and will then embarrass our attempt to continue even these in full health.

A number of our staff have gone on leave of absence in order to accept posts in the armed services or other war agencies, under conditions where we have been temporarily relieved of salary payments. Their names have remained on our rolls, we have continued their benefits under our retirement provision, and, where conditions warranted, we have supplemented their government salaries. Moreover, we still include their salaries in making up the departmental estimates, for we expect these men back in time, and the inclusion of their salaries hence gives a true picture of our situation. For this reason there will be more than the usual unexpended funds reported by the departments at the end of this year. Part of the excess has been used, by transfer within department budgets, to defray certain unusual extra costs of service to government which it was felt should not be included in the reimbursement account, but the bulk of such salary provision will return to us. It can be placed in reserves, where it will need to be drawn upon for current operating expenses next year in view of sharply decreased income.

In accordance with action of the Board of Trustees at its last meeting, a General Reserve Fund has been established by merging the former Special Emergency

Reserve Fund with the Insurance Fund. At the same time the former so-called Reserve Fund was designated the Capital Reserve Fund, inasmuch as the principal of this fund originated as a result of stipulation of the Founder of the Institution in connection with his gift of 1911. In view of these arrangements, insurance protection for Institution property has now been increased through commercial agencies. Fire insurance, with extended coverage, has been written for a five-year period, and war damage insurance has been secured on a yearly basis on property which may be subjected to such hazards.

As an added protection in connection with war risk, duplicate copies of important or irreplaceable administrative and financial records have been deposited elsewhere than in the Administration Building.

In an effort to cooperate with the appeal of the government for voluntary purchase of war bonds, the Institution has opened a special bank account for custody of funds derived from payroll deductions authorized by staff members for such purchase of government securities.

Since its organization the Institution has enjoyed exemption from federal taxes and from real-estate taxes in the District of Columbia. During recent months consideration has been given by authorities of the District of Columbia to the question of placing the Institution on the tax roll along with a small group of other organizations which own real estate in Washington but whose programs are nation-wide in scope. There is indication that this question will be reasonably resolved, and that the Institution's present status will be maintained.

REVIEW

Despite interruptions to established research plans and withdrawal of many members of the scientific staff for war research, reports of Directors of Departments indicate an amount of activity in connection with the Institution's normal program which is remarkable, although it is now rapidly decreasing. The customary interpretative statements of these activities appear in the Directors' reports in the Year Book. The following brief additional comments will serve as an introduction to the full formal record.

Although many staff members of the Mount Wilson Observatory are giving full time to war service, and essentially every remaining member of the scientific staff is contributing in some way toward the solution of military problems, the program of astronomical research has not altogether ceased and a few important advances have been made. Among the results of the

many investigations undertaken at the Observatory, especial reference may be made to the increase in our knowledge of solar prominences, solar rotation, and the general magnetic field of the sun through the application of powerful interference methods; to the analysis of the gaseous clouds of interstellar space; and to the probable solution of the problem of long standing of the direction of rotation of the outer systems of stars known as the extragalactic spiral nebulae. The conclusion that the spiral arms are trailing in all such nebulae now seems to be well founded. A discovery of some dramatic interest is that of the remnants of Kepler's celebrated supernova of 1604. Faint wisps of nebulosity scattered over a field some 80 seconds in diameter and a small fan-shaped nebula showing a high radial motion seem to be all that remains of the expanding shells

thrown off in the great outburst of the original star.

Activities at the Geophysical Laboratory and the Department of Terrestrial Magnetism have been directed so exclusively to war research that there is little to report from these laboratories. On the basis of service which the cyclotron at the Department of Terrestrial Magnetism will be able to render in connection with war research, and at the instance of the Committee on Medical Research of OSRD, priorities have now been obtained for materials necessary for completion of this apparatus. It is expected that the cyclotron will be available for use during the coming winter.

Dr. Spoehr, Chairman of the Division of Plant Biology, reports a number of interesting experiments during the past year on the variability of the photosynthetic process, on certain structural elements in the higher plants, and on differences and relationships in climatic races of flowering plants. Several projects have recently been completed having to do with the influence of a desert environment on plant growth. It has been discovered that diatoms and related plants contain chlorophylls which are different from those of land plants. This is indication of fundamental differences in the photosynthetic apparatus between the two groups of plants. It will be of importance to determine whether this diversity is reflected in differences in the mechanism of the photosynthetic process and in the nature of the resulting products.

The work of the Department of Embryology has continued to develop along lines set forth by the Director, Dr. Corner, in last year's report. A significant addition to the collection of embryos is announced this year. Dr. Hertig and Dr. Rock, of Boston, working during the past six years

with financial aid from the Carnegie Corporation, have obtained a remarkable collection of human embryos of very early stages. By study of these specimens our knowledge of the development of the human embryo has been pushed back about one week, to the eighth day of gestation. Plans for obtaining still earlier stages are being worked out. This year marks also completion of a long study of the development of the rhesus monkey by Dr. Streeter, Dr. Heuser, and Dr. Hartman. Important studies on the organs accessory to the embryo, which have reached the stage of publication, are those of Dr. Flexner and Dr. Gellhorn on the physiology of the placenta, and of Dr. Speert on various physiological states and hormone relationships of the mammary gland.

Under the leadership of Dr. Demerec, there has been continuation of effective cooperation between the Department of Genetics and the Long Island Biological Association at Cold Spring Harbor. It is a pleasure also to report that Dr. Blakeslee, who retired as Director of this Department last year, has accepted a research post at Smith College, where, with cooperation of the Institution, he will have continued opportunity to go on with *Datura* researches under favorable conditions.

Detailed studies at the Department of Genetics, made by Dr. Demerec, Dr. Hollaender, and Dr. Fano, of genetic effects produced by X rays, ultraviolet rays, and neutrons show consistent differences between the actions of these radiations. As compared with gene mutations, fewer chromosomal breaks are produced by ultraviolet radiation than by X rays; whereas neutrons show a higher rate of chromosomal breaks than X rays. Working with maize, Dr. McClintock has obtained important evidence regarding the fusion of broken chromosome ends. She found that

broken ends retain their capacity for fusion for a certain period of time after breakage, but that after that period has passed they "heal" and are unable to fuse again. Nearly six years of study of the role of hormones in the regulation of the maternal instinct in rats have been concluded by Dr. Riddle and his associates, who found that pituitary-gland hormones play an important part in the production of stimuli that result in unlearned maternal behavior. Dr. Warmke has been cooperating with the Bureau of Plant Industry of the U. S. Department of Agriculture on several problems arising from the present war emergency. He is experimenting with the rubber-producing Russian dandelion and with fiber-producing hemp.

The small staff of the Nutrition Laboratory has been engaged in important war research in cooperation with groups at the Harvard Medical School. Work has continued, however, on respiratory exchange, by measurements on diabetic patients through cooperation with Dr. Joslin and Dr. Root, and certain studies on basal metabolism have been continued.

It has been possible for the most part for the Division of Historical Research to carry through the program of field studies planned by Dr. Kidder for the past season, in a series of archaeological explorations and excavations in Yucatan, Guatemala, Honduras, and Nicaragua. These projects have also been of interest in supplementing the government's program of inter-American cultural relations. Certain members of the staff of the Division have remained in Central America to complete their work. Additional data have been obtained concerning the discovery of human footprints in Nicaragua, and this was reported to the members of the Board. At the important archaeological site of Kaminaljuyu, outside Guatemala City, rich caches of pottery and jades have been found, and also many fine stone sculptures. Studies of such material which are now proceeding will add much to our understanding of the events of Maya history. Knowledge which staff members of this Division possess with regard to geographical and economic conditions in Central America is proving of aid in connection with the government's war program.

STEWART PATON

Stewart Paton died on January 7, 1942, in his seventy-sixth year. He was elected a Trustee of the Institution in December 1915, and at the time of his death had been in continuous service for a longer period than any other member of the Board. At the meeting of the Board on December 15, 1916, he was elected a member of the Executive Committee, on which he served until his resignation on account of ill health, in December 1938.

Dr. Paton was greatly interested in affairs of the Institution, and his counsel and advice were often sought, particularly

with regard to activities in the fields of biology and genetics. His personal contributions as a scientist and physician concerned studies in human behavior and took the form of pioneering efforts in every forward movement in psychiatry in the United States during the period of his career.

He takes his place as a member of that eminent group of former Trustees consisting of John S. Billings, S. Weir Mitchell, Theobald Smith, William S. Thayer, Henry P. Walcott, and William H. Welch.

REPORTS OF DEPARTMENTAL ACTIVITIES AND COOPERATIVE STUDIES

ASTRONOMY

Mount Wilson Observatory

Special Projects

TERRESTRIAL SCIENCES

Geophysical Laboratory

Department of Terrestrial Magnetism

Special Projects

BIOLOGICAL SCIENCES

Division of Plant Biology

Department of Embryology

Department of Genetics

Nutrition Laboratory

Special Projects

HISTORICAL RESEARCH

Division of Historical Research

Special Projects

MOUNT WILSON OBSERVATORY

Pasadena, California

WALTER S. ADAMS, *Director*

Since the entry of the United States into the war, two members of the scientific staff have been given indefinite leave of absence to devote all their time to investigations on military problems. A third member has been engaged, to the exclusion of all other work, upon various projects initiated by the Instrument Section of the National Defense Research Committee. The Office of Scientific Research and Development has entered into contracts with the Carnegie Institution for such work. Nearly all the remaining members of the staff have helped to contribute, each according to his special ability, to the solution of the many types of questions which have arisen in these investigations. A very large part of the time of the optical shop (enlarged considerably during the year), of the instrument shop, and of the engineering staff has been given to the design and construction of the instruments and equipment used in research projects relating to the war.

Two members of the operating group on Mount Wilson volunteered for service in the military forces and have been in the Army since early in 1942.

Although the scientific work of the Observatory has necessarily been maintained under considerable difficulties, the year has been an active one in all its fields of research. The gradual decrease in sunspot activity has favored investigations requiring a quiescent sun, such, for example, as spectrographic studies of solar rotation and the general magnetic field of the sun. Observations of prominences have been numerous and have been aided greatly by the use of the quartz monochromator of

the Öhman type designed for this purpose. No sunspots of the new cycle have as yet appeared, but they may normally be expected within the next year or two.

An extensive investigation of the infrared solar spectrum to a limit of λ_{13500} , made in cooperation with Mrs. Sitterly, of the Princeton Observatory, is nearing completion. The separation of solar from telluric lines and their identification according to element and energy level should make this catalogue of great value to solar physicists.

In the field of stellar research, our knowledge of the nearer stars has been considerably extended by the continuing program of the measurement of distances by the trigonometric method. The intrinsic luminosities of stars derived in this way have been supplemented to a great extent, for more distant stars, by computations based upon proper motions and radial velocities as well as upon certain spectral characteristics.

The fundamental importance of accurate determinations of stellar brightness has been recognized in several recent investigations. In one of these the scale of photographic magnitudes has been extended to $20^m.5$, primarily for the use of observers of faint stars in clusters and extragalactic nebulae. A very complete discussion of the colors of the stars in the Mount Wilson Polar Catalogue has led to interesting conclusions respecting space absorption in this region, mean effective wave lengths, and the probable departure of stars from black-body radiation. Photoelectric measures of B-type stars through various filters indicate that the nature of ab-

sorbing dust is much the same throughout interstellar space.

Stellar spectroscopy has always formed one of the major fields of investigation of the Observatory. In the past year especial attention has been given to physical studies of certain classes of variable stars and individual stars of exceptional interest. Among the classes of variable stars the results have shown numerous interrelationships as regards luminosity, distribution, and motion; and individual spectra have served to emphasize remarkable problems in spectral variation, bright-line emission, and combinations of widely differing spectral characteristics. As an example, the discussion of the orbit of a spectroscopic binary of the Wolf-Rayet type throws considerable doubt upon the usually accepted view of the origin of the emission bands.

The structure of the interstellar lines of ionized calcium in numerous stars has been examined with exceptionally high dispersion, and double or multiple lines have been found in a large majority of the stars. The results afford a means of determining the distribution in various parts of the sky of individual gaseous clouds distinguished from one another by differences of motion in the line of sight.

Investigations of galactic nebulae have to a large extent centered about those nebulae associated with outbursts of novae or supernovae. Direct photographs and spectroscopic studies of Nova Herculis (1934) show the emergence of an elliptical ring due to an expanding shell of finite thickness. The clearly separated diffuse and filamentary nebulosities of the Crab nebula, probably a remnant of the supernova of 1054, have quite different spectra, that of the diffuse part being continuous, that of the filaments consisting of bright lines. Theoretical considerations indicate that the supernova before its outburst was

a massive star of low hydrogen content, and that the greater part of its mass was lost in the outbreak, leaving a relatively small star of high temperature.

An interesting and somewhat dramatic discovery is that a small fan-shaped nebula and various wisps of nebulosity scattered over a field 80" in diameter in the constellation of Ophiuchus are almost certainly remnants of Kepler's supernova of 1604. The region is heavily obscured, but the spectral characteristics of the fan-shaped nebulosity and its relatively high radial velocity afford strong evidence that it forms part of an expanding nebula.

A detailed study of the pattern of obscuration in several extragalactic spiral nebulae indicates clearly which is the nearer side of these objects and hence the direction of inclination. When combined with the spectrographic data for numerous nebulae, these results define without ambiguity a direction of rotation, probably characteristic of extragalactic nebulae in general. The arms of the spirals are found to trail behind the nucleus. This gives what appears to be a definite answer to a problem of long standing in nebular research.

In addition to determinations of motions in extragalactic nebulae which have been accumulated rapidly in recent years, it has now become possible to make physical studies of the spectra of some of the brighter nebulae. Such an investigation of the nuclear emission of three spirals through measurements of line widths and contours has been completed during the past year.

Researches in the physical laboratory serve the purpose of contributing data both for the analysis of atomic and molecular spectra and for the study of astrophysical problems. Observations of the

spectra of rare earths and identification of their lines in the sun and stars afford an illustration of both purposes. Similarly, measurements in the laboratory of the statistical factors for spectral lines known

as "*f*-values" have been applied to a determination of the abundance of iron in the sun. The method has almost limitless applications to the spectra of the brighter stars.

STAFF AND ORGANIZATION

RESEARCH DIVISION

Solar Physics: Seth B. Nicholson, Harold D. Babcock, Joseph Hickox, Edison Hoge, Edison Pettit, Robert S. Richardson, Mary F. Coffeen, Elizabeth S. Mulders, Myrtle L. Richmond, Louise Ware.

Stellar Motions and Statistics: Adriaan van Maanen, Ralph E. Wilson, A. Louise Lowen.

Stellar Photometry: Walter Baade, Harold Weaver, Mary C. Joyner.

Stellar Spectroscopy: Walter S. Adams, William H. Christie, Theodore Dunham, Jr., Milton L. Humason, Alfred H. Joy, Paul W. Merrill, Roscoe F. Sanford, Gustaf Strömberg, Olin C. Wilson, Ralph E. Wilson, Ada M. Brayton, Sylvia Burd, Cora G. Burwell, A. Louise Lowen.

Nebular Photography, Photometry, and Spectroscopy: Edwin P. Hubble, Walter Baade, Milton L. Humason, Rudolph Minkowski, Sylvia Burd.

Physical Laboratory: Arthur S. King, John A. Anderson, Robert B. King.

Editorial Division: Paul W. Merrill, editor; Elizabeth Connor, librarian; Alice S. Beach, secretary and stenographer.

Alfred H. Joy has served as Secretary of the Observatory throughout the year.

RESEARCH ASSOCIATES

Sir James Jeans, Dorking, England; Henry Norris Russell, Princeton University; Frederick H. Seares, Pasadena; Joel Stebbins, University of Wisconsin.

Dr. Russell spent the months of March and April 1942 in Pasadena, engaged chiefly in a term analysis of spectra of rare

earths, especially neutral and ionized gadolinium. As always, his discussions of astrophysical problems with members of the staff have been stimulating and suggestive. Dr. Seares with the assistance of Miss Joyner has completed an extensive discussion of the colors of stars in the Mount Wilson Polar Catalogue, deriving effective wave lengths and color temperatures and applying the results to black-body radiators of different temperatures. This investigation is now ready for publication. Dr. Stebbins during the summer of 1941 carried on measurements of the colors of numerous early-type stars and nebulae with his photoelectric photometers, being assisted in the observations by Mr. Bart Bouricius, of the University of Wisconsin.

TEMPORARY ASSOCIATES

Dr. S. A. Mitchell, Director of the Leander McCormick Observatory, spent the months of July and August 1941 in Pasadena measuring the radial velocities of faint stars in the fields of stars of known proper motion from spectrograms which he obtained with the 60-inch telescope. Dr. John C. Duncan, Director of the Whittaker Observatory, continued his direct photographic observations of selected nebulae and star fields. Dr. Erik Holmberg, of the Observatory of Lund, carried on nebular research during the summer and autumn months of 1941. He returned to Sweden in November 1941. Dr. G. P. Kuiper, of the Yerkes Observatory, spent two weeks of May 1942 in Pasadena in the measure-

ment of the proper motions of faint dwarf stars. Miss Elizabeth Scott, of the University of California, assisted in several investigations in stellar statistics during a stay of two months in the summer of 1941. Lieutenants Evinay and Erokan of the Turkish army visited the Observatory during the months of May and June 1942, for the purpose of studying its equipment and scientific program. Their journey was sponsored by the Department of State. Dr. Carl K. Seyfert, National Research Fellow, has continued his work throughout the year on the spectra of extragalactic nebulae.

Many other scientists have made brief visits to Mount Wilson and Pasadena during the past year.

INSTRUMENT CONSTRUCTION

Design: Edgar C. Nichols, Harold S. Kinney.
Optical Shop: John S. Dalton, Donald O. Hendrix.

Instrument Shop: Albert McIntire, foreman; Elmer Prall, Myo C. Hurlbut, Fred Scherff, Oscar Swanson, Albert Labrow, Donald W. Yeager, machinists; Robert W. Kingan, assistant machinist; James Chapman, pattern maker; Harry S. Fehr, cabinet maker.

OPERATION AND MAINTENANCE

Office: Anne McConnell, bookkeeper; Sarah Shaw and Dorothea Neuens, stenographers and telephone operators.

Operation: Ashel N. Beebe, superintendent of construction; Sidney A. Jones, engineer; Kenneth de Huff, assistant engineer; Thomas A. Nelson, Boyd Thompson, Floyd Day, Louis S. Graf, night assistants; Anthony Wausnock and Mrs. Wausnock, stewards; Charles Dustman, Arnold T. Ratzlaff, George W. Foster, Lester Shade, janitors.

Several of the individuals whose names are listed above have been associated with the Observatory for but part of the year.

OBSERVING CONDITIONS

The extraordinarily wet winter of 1940-1941 was followed by an abnormally dry season in 1941-1942, the total precipitation amounting to only 20.97 inches. The snowfall was 30 inches. Observing conditions, as indicated by the accompanying table applying to the 60-inch telescope, were very close to the normal.

Owing to wartime conditions, the weekly evening lecture and public observations with the 60-inch telescope were discontinued in December. The exhibit hall on Mount Wilson with its numerous astronomical photographs and models has, however, been open every afternoon, and the regular daily lectures and demonstrations in the dome of the 100-inch telescope have been maintained.

MONTH	OBSERVATIONS		
	All night	Part of night	None
1941:			
July.....	22	7	2
August.....	25	4	2
September.....	21	6	3
October.....	15	6	10
November.....	19	6	5
December.....	6	6	19
1942:			
January.....	11	11	9
February.....	12	7	9
March.....	13	9	9
April.....	5	14	11
May.....	24	4	3
June.....	28	2	0
Total.....	201	82	82
Mean 30 years...	204	85	75

SOLAR RESEARCH

SOLAR PHOTOGRAPHY

Photographs of the sun were made on 301 days of the year by Hickox, Hoge, Nicholson, and Richardson. These were distributed as follows:

Direct photographs	604
<i>Ha</i> spectroheliograms of spot groups, 60-foot focus	760
<i>Ha</i> spectroheliograms, 18-foot focus ..	1,170
<i>Ha</i> spectroheliograms, 7-foot focus ..	4,000
K ₂ spectroheliograms, 7-foot focus ..	18,000
K ₂ spectroheliograms, 18-foot focus ..	1,130
K prominences, 18-foot focus	1,450

SUNSPOT ACTIVITY

During the calendar year 1941 sunspot activity decreased notably from that of the preceding year. Observations were made on 294 days, on 2 of which no spots were visible. The monthly means of the number of groups observed daily during the past two and one-half years are shown in the accompanying table.

In 1941, 252 sunspot groups were observed, 119 less than in 1940. The northern hemisphere was the more active, showing 24 more groups than the southern hemisphere.

MONTH	DAILY NUMBER		
	1940	1941	1942
January.....	4.3	4.8	3.3
February.....	5.2	5.5	4.4
March.....	7.7	5.0	4.9
April.....	6.5	2.7	5.2
May.....	5.3	3.1	2.6
June.....	8.3	4.7	1.3
July.....	6.9	5.2	...
August.....	9.2	5.4	...
September.....	5.8	4.9	...
October.....	5.3	3.7	...
November.....	6.8	3.4	...
December.....	6.5	3.7	...
Yearly average.....	6.5	4.3	...

SUNSPOT POLARITIES

Magnetic polarities in each spot group have been observed at least once, so far as possible. The classification of the groups observed between July 1, 1941 and June 30, 1942 is given in the accompanying table. As usual, "regular" groups in the northern hemisphere are defined as those in which the preceding spot has N (north-seeking) polarity and the following spot S polarity. In the southern hemisphere the polarities are reversed.

HEMISPHERE	POLARITY		
	Regular	Irregular	Unclassified
North.....	93	1	41
South.....	58	4	36
Whole sun....	151	5	77

SOLAR PROMINENCES

The monochromator designed for the *Ha* line has been used extensively by Pettit in studies of the solar prominences. Most of the photographs have been made on 35-mm film at intervals of 1 minute with a telescope of 45 feet equivalent focal length. Especial attention has been given to eruptive prominences, coronal prominences as related to sunspots, and pairs of interactive prominences with connecting streamers. In prominences so far studied, the material moves only in one direction along the streamers and no exchange of matter seems to occur. This implies that two prominences can have masses of gas with electrical fields of opposite sign, a result of considerable theoretical interest. The length of such streamers varies from a few thousand to several hundred thousand kilometers; the breadth varies much less, being usually from 500 to 1000 km

and only rarely 4000 or 5000 km. Broad streamers deplete a prominence rapidly, two streamers 5000 km wide once having been observed to reduce a prominence 70,000 km high and 55,000 km wide to a height of 46,000 km within an hour.

Further study of 43 eruptive prominences shows that in 31 of them successive velocities were multiples by small whole numbers within the allowable errors of observation. In 12 an occasional velocity, usually the last of the series, was a multiple of the second preceding velocity instead of the first. This modification of the suggested law is required to explain only 12 of the total of 86 velocities involved in the study.

There seems to be no especially favored velocity in eruptive prominences, and the frequency of any velocity is roughly inversely proportional to the velocity raised to the power 0.8. Measurements of both top and bottom of eruptive prominences show that as the gas cloud rises, the changes in velocity of the various parts take place within a few minutes of the same instant and in some cases nearly simultaneously. The heights at which changes in velocity occur show some tendency to maxima of frequency at 62,000 and 162,000 km above the sun, but prominences have been observed to pass through both heights without changes in velocity.

A study has been made by Pettit with the 150-foot tower telescope of the widths of lines in the spectra of prominences and of the same lines in laboratory sources at known temperatures. In laboratory spectra the widths of the hydrogen and calcium lines agree with their theoretical widths if it is assumed that the measurements include intensities greater than 8 per cent of the maximum. In the spectrum of a quiescent prominence, $H\alpha$ and $H\beta$ show similar agreement with the theoretical width if a temperature of about 5700°K

is assumed. No suitable quiescent prominence has been available for H and K, but measures on active prominences show widths much greater than the theoretical, the width in the streamers of one active prominence being three times that calculated. Random group velocities at right angles to the streamers not exceeding 7 km/sec would satisfy the observed line widths.

ULTRAVIOLET SOLAR SPECTRUM

A concave-grating spectrograph and the equipment at the Hale Solar Laboratory have been utilized by Babcock in a variety of solar investigations. Among these is a study of the spectrum of the disk, spots, and chromosphere in the region $\lambda 3250$ to the ultraviolet limit. Numerous faint lines not recorded by Rowland have been observed, and a study has been made of the intensities of some of the strong lines near $\lambda 3000$ for comparison with their multiplet relations. A special type of polarizer has proved useful in avoiding the effects of scattered light in the spectrograph.

Some drift-curves across the solar disk at 200-angstrom intervals between $\lambda 4300$ and $\lambda 3000$ have been obtained by Pettit with a 21-foot grating spectrograph and quartz monochromator. A photoelectric amplifier and galvanometer formed the recording device. The curves show a definite change in the amount of limb darkening in the 200-angstrom intervals.

INFRARED SOLAR SPECTRUM

The manuscript of the table of solar-spectrum lines in the region $\lambda\lambda 6600\text{--}13500$, in preparation by Babcock and Mrs. Sitterly with the assistance of Mrs. Coffeen, is now at Princeton, and the text is being completed. Identifications are being made through comparisons of disk and spot spectra and through structural analysis of

laboratory lines. About one-half of the 7500 lines are known to be telluric and about one-quarter of solar origin. Over 60 per cent of the known solar lines have been identified, and most of these have been assigned to multiplets. A very weak band due to atmospheric oxygen has been discovered near $\lambda 10700$.

A slight systematic difference, amounting to about 0.01 wave number, has appeared in the region $\lambda\lambda 7000-7700$ between the wave-length scale of these lines and that of the Allegheny Observatory. Although too small to affect the interpretation of the results, it is now under investigation.

SOLAR ROTATION

Two studies of the rotation of the sun are in progress, one by Babcock, who has used the spectroscopic method, and one by Nicholson and Miss Ware, who have measured the motions of sunspots.

Babcock has combined a Lummer plate with a concave-grating spectrograph in observations of 7 lines in the green region of the spectrum. The material used is equivalent to about 100 ordinary grating spectrograms. The data give an equatorial rotational velocity close to that found by Adams with a grating spectrograph in 1908, and definitely higher than most of the values which have been announced since that time. Observations in progress include points well in on the solar radius, since the method is highly sensitive and the effects of scattered light can be eliminated by this means.

In their measurements Nicholson and Miss Ware have used material extending over four sunspot cycles. The observations have been limited to single unipolar spots in an attempt to eliminate the effect of the forward motion of the preceding spots of bipolar groups due to gradual

separation of the preceding and following members. The angular rotation is found to be $0^{\circ}.05$ less per day than that previously derived at the Greenwich Observatory. The variation with latitude is essentially the same as that found at Greenwich.

Referred to a photosphere rotating at this slower rate, the preceding spot of a bipolar group moves forward as the group lengthens. After the following member of the group disappears, however, the preceding spot stops but does not return toward its original position as it does when referred to a faster-rotating photosphere.

GENERAL MAGNETIC FIELD OF THE SUN

Babcock has adapted the Lummer plate and accessories, previously used with the red lines $\lambda 6173$ and $\lambda 6302$, for measurements of the general magnetic field with the lines $\lambda 5250$ and $\lambda 5329$. Reductions are now in progress on 80 spectrograms which include these lines.

THE H AND K LINES AND MAGNETIC STORMS

Although there are good theoretical reasons for believing that terrestrial magnetic storms are caused by streams of charged particles ejected from active solar regions, so far no observational evidence has been obtained of the presence of such streams. To test the suggestion made by Chapman that a cloud of charged particles moving earthward might be detected through faint absorption lines on the violet side of the solar lines, Richardson has compared photographs of the H and K lines taken during a magnetic storm with similar photographs at a period of magnetic calm. Observations were obtained with the Snow telescope during the central period of the violent storm of September 18, 1941, and on one day preceding

as well as during the equally violent storm of March 1, 1942. These would seem to be most favorable cases so far as time is concerned.

Preliminary reductions of the microphotometer tracings give no definite evi-

dence of any faint components of the normal calcium lines before and during two of the most violent magnetic storms of the present cycle. If such lines exist, they must have an intensity less than 5 per cent of that of the continuous background.

PLANETS AND SATELLITES

At present no reliable determination of the mass of the planet Pluto exists, solutions depending upon perturbations of the major planets having so far proved unsatisfactory. Richardson has made an attempt to determine the mass from an unexplained discrepancy in the time of perihelion passage of Halley's comet in 1910 as given by the highly accurate computations of Cowell and Crommelin.

Special perturbations were calculated from 1844 to 1908 at intervals of 512 days, on the assumption of a mass of unity for Pluto. Within the errors of the computations these corrections indicated no change

in the time of perihelion passage. Further calculations extended to 1975 make it doubtful whether Halley's comet is ever affected sensibly by the attraction of Pluto.

The investigation indicates that a planet of mass unity moving in the plane of the orbit of Halley's comet at an aphelion distance 0.1 astronomical unit greater than that of the comet would delay its perihelion passage by 6 days.

Several of the faint satellites of Jupiter have been reobserved during the year by Nicholson. The elements of the orbit of J IX have been improved and an ephemeris has been calculated for opposition.

MISCELLANEOUS STELLAR INVESTIGATIONS

TRIGONOMETRIC PARALLAXES AND PROPER MOTIONS

The year has seen the completion of the 500th parallax determined by van Maanen in his extensive program. Both reflectors are used, the observations being made at the Cassegrainian focus of the 60-inch and the Newtonian focus of the 100-inch telescope. Although the focal lengths are in the ratio of nearly 2 to 1, the probable error of the parallaxes with the two instruments is closely the same, about $0''.0065$. This comparison omits 27 stars which were observed with a rotating sector at the 100-inch telescope and were apparently subject to exceptional sources of error.

In recent years particular attention has been given in the parallax program to stars of large proper motion and presumably

faint luminosity. More than 130 stars with absolute photographic magnitudes fainter than $+10$ have been added by van Maanen to a list of less than two dozen such stars known in 1913. Parallaxes have been determined for 17 of the 21 stars with absolute magnitudes fainter than $+15$.

Studies in proper motions have included measurements by R. E. Wilson of fields containing variable stars of the δ Cephei and RR Lyrae classes, and by van Maanen of areas in the Hyades region and of the open cluster Messier 67. Two stars, out of nine for which Dr. Zwicky had found small color indices, are probable members of the Taurus cluster and should be white dwarfs. Three other faint stars have been found to share the motion of the cluster in addition to one in the region of T

Tauri of photographic magnitude about 16.5 (corresponding absolute magnitude $+13.7$).

The results found for Messier 67 are based upon two photographs of the cluster taken at the Cassegrainian focus of the 60-inch telescope with an interval of 21 years. An absolute motion of $0''.0087$ in position angle 230° is given by the 284 stars probably belonging to the cluster.

EXTENSION OF THE PHOTOGRAPHIC SCALE IN CERTAIN SELECTED AREAS

During the year final photographic magnitudes down to $20^m.5$ have been derived by Baade for Selected Areas 51, 71, 85, and 89, again with the cooperation of H. Weaver. Selected Area 71 was included at the request of Dr. Shapley, who intends to use this area for a final check of the magnitude scales in the Magellanic Clouds. The results for seven areas will be ready for publication this fall. To check the constancy of the platinum filter, its absorption constant was redetermined in the summer of 1941: (*a*) with a photoelectric cell at the 60-inch by Professor Stebbins, and (*b*) from plates of the Polar Sequence. The new absorption constant agrees within less than $0^m.01$ with the older value obtained in 1937.

EFFECTIVE WAVE LENGTHS AND COLOR TEMPERATURES

With the assistance of Miss Joyner, Seares has continued his discussion of the colors of stars provided by the Mount Wilson Polar Catalogue. An important preliminary was the determination of mean effective wave lengths as a function of temperature for the photographic and the photovisual magnitudes of the international system. It thus became possible to compute the differential corrections for atmospheric extinction depending on stel-

lar temperature and to obtain finally the relation between spectral type and color index for zero air mass. This relation is also fully corrected for space absorption. The mean color excess as a function of distance caused by the absorption in the polar region was found directly from the observational data. The differential absorption depending on temperature was computed on the assumption that the absorption varies inversely as the wave length. Incidentally, it was shown that for such calculations the direct substitution of the effective wave length into the absorption formula gives the same result for the total photographic or photovisual absorption as the complete integration over the wave-length interval.

An important application of the effective wave lengths is the calculation of theoretical color indices (international system) for black-body radiators of different temperatures. Comparison of these results with the spectrum-color relation then gave color temperatures for the different spectral types. With type A5 set at 11000° to fix the zero point, the result for gKo is 4150° . Similar calculations based on the photoelectric color indices of Stebbins and his associates give 3750° . The mean errors are only a fifth of the 400° discrepancy, which in part at least seems to be real and attributable probably to departures from black-body radiation in the stars.

PHOTOELECTRIC MEASURES OF STARS

Stebbins and Whitford have continued the measures of stars with a photoelectric cell and filters which isolate six spectral regions from 3500 to 10000 Å. The small deviations from the $1/\lambda$ law of interstellar absorption, derived from reddened B stars, are found to be the same for stars in widely separated parts of the sky, showing that the nature of the dust in space is much the same everywhere.

Measures of the typical variable star δ Cephei give light-curves in six colors which provide new material for a theoretical discussion of the cause of this class of stellar variation. The amplitude of variation at 3500 Å is four times the amplitude at 10000 Å, and there are other significant differences in the curves for different wave lengths.

ABSOLUTE MAGNITUDES OF STARS

From a study of the mean absolute magnitudes of long-period variables based upon radial velocities and proper motions, R. E. Wilson and Merrill have found that the luminosities of these stars are related to the period of light-variation. A period-luminosity curve is obtained in which \bar{M} reaches a maximum of -2.7 for periods around 175 days, falling to -2.2 at 150 days and $+0.6$ at 450 days.

The relationship has been used to study the total motions of these stars. The mean speed is high, 74 km/sec, and the velocities exhibit the characteristics of the motions of high-velocity stars of other classes. The apices of motion lie predominantly in that half of the sky opposite to the apex of the solar motion and to the direction of galactic rotation. The preferential motion is in the same direction as that of stars in general, but for stars with the higher speeds this shifts to a direction

nearly radial with respect to the galaxy. The motions of the long-period variables are explained reasonably on the hypothesis of galactic rotation.

A similar investigation by R. E. Wilson of the mean absolute magnitudes of irregular variables of type M gives a value $\bar{M} = -1.1$, essentially the same as that found for the long-period variables. About 10 per cent of the stars are supergiants, for which $\bar{M} = -3.4$; the remainder are ordinary giants with $\bar{M} = -0.9$. No correlations appear to exist with spectral type, general order of period, or character of light-variation. Excellent agreement is found with the values derived by Joy from spectroscopic criteria.

The average space motion of the irregular variables, 54 km/sec, is about midway between that of nonvariable giants of type M and that of the long-period variables; and the group motion, $V_0 = -28.1$ km/sec, shows somewhat similar behavior. In their kinematic properties the irregular variables seem to be closely related to the long-period variables, but in their physical properties the relationship to nonvariable stars of the same spectral type seems to be more prominent.

Strömberg has now extended to giant stars of all spectral types from F to M his studies of the systematic corrections to be applied to spectroscopic absolute magnitudes.

STELLAR SPECTROSCOPY

The stellar spectroscopic equipment has remained without important changes or additions throughout the year. The two-prism spectrograph with collimating mirror, described in last year's report, has been used extensively at the 100-inch telescope and has proved most useful. Cameras ranging from 18 to 1.3 inches in focal length, including two of the Schmidt

type, provide for the study of spectra of stars as faint as photographic magnitude 16, as well as for observations of extragalactic nebulae.

Increases in the sensitiveness of photographic emulsions, especially some of those developed for astronomical work by Dr. Mees, of the Eastman Kodak Company, have added greatly to the efficiency of the

spectrographic instruments. Of particular value for the coude spectrograph have been the 103a-O plates, which through their remarkable sensitivity to blue and violet light have brought within the range of observation stars nearly a magnitude fainter than those observed previously.

About 1500 spectrograms have been obtained with the various instruments during the year.

RADIAL VELOCITIES

Observations of radial velocity have been made of many stars under study primarily for statistical purposes, such as those in the Selected Areas by Strömberg and Christie, in the Taurus group by R. E. Wilson, and in the general radial-velocity program by several observers. Only 20 stars in the Selected Area program are still unobserved. Special classes of stars whose physical characteristics are being investigated have also been observed for radial velocity. These include irregular M-type variables and some eclipsing variables observed by Joy, stars of types N and R observed by Sanford, and numerous individual stars of especial interest. The differences in displacement shown by different lines have been studied by Merrill in stars of early type with emission lines. Five stars of type F with bright hydrogen lines have been discovered, in one of which, HD 59771, the measures show a rapidly expanding hydrogen atmosphere. This is most exceptional for stars with a relatively cool photosphere, and suggests an analogy with the rapid motions of prominences above the sun's reversing layer.

Determinations of the orbits of four spectroscopic binaries, including the companion of Rigel, have been completed by Sanford. For Rigel B, spectrograms of dispersion 10 Å/mm, taken with the 32-inch coude spectrograph, have been used to a large extent.

Three new spectroscopic binaries of the Wolf-Rayet type of spectrum have been discovered by O. C. Wilson. One eclipsing binary of this type, HD 193576, has been the subject of an extensive study, measures of the total absorption of the *Hγ* line of the B-type component before and after eclipse being combined with photometric data from the light-curve to derive the relative dimensions of the two stars. The Wolf-Rayet star is found to be the larger. Wilson then investigated the validity of the hypothesis of an expanding envelope as the source of the emission bands in the spectrum. On the assumption of this hypothesis, one of two phenomena should be observable: (*a*) If the envelope is small, the part behind the eclipsing star should be occulted and the emission bands should be shifted toward the violet; (*b*) if the envelope is large, there should be a time lag between the observed and the predicted eclipses. Neither effect has been observed, and the evidence seems to throw considerable doubt upon the usual explanation of the origin of the emission bands.

The velocity-curve of the star HD 142983 (48 Librae), which has been rising ever since a remarkable minimum in 1937, recently reversed its upward trend, according to observations by Merrill and Sanford, a maximum apparently having occurred in 1941. The future course of the displacements shown by the various lines will be followed with interest.

Humason and Joy have continued observations of faint dwarf stars for radial velocity and spectral type. Most of them are of type M, bright hydrogen lines and bright H and K being frequent. A list of 17 M-type dwarf stars with hydrogen emission has been published.

VARIABLE STARS

A study by Joy of the spectra of 118 M-type variables with light-curves less regular

than those of the \circ Ceti class leads to the following conclusions: (1) The spectroscopic absolute magnitudes based upon the 1935 system show the existence of supergiants such as α Orionis with magnitudes between -2.0 and -4.5 , but indicate that 90 per cent of the stars are normal giants like the \circ Ceti stars with a mean absolute magnitude of -0.9 . These results are in remarkably good agreement with those calculated by R. E. Wilson from proper motions and radial velocities. (2) The supergiants show a marked galactic concentration with a mean latitude of 11° , but the normal giants show no concentration. (3) Spectral types of supergiants, Mo to M5, are on the average earlier than those of the normal giants. (4) Corrected for solar motion, the average residual radial velocities are 18.2 km/sec for the supergiants, and 26.1 km/sec for the giants. Stars with the shorter periods show the larger velocities and the greater dispersion in velocity. (5) The mean displacement to the violet of the bright lines with respect to the absorption lines in the spectra of 17 stars showing faint emission lines at certain phases is 8.9 km/sec. This is in agreement with the results for stars of the \circ Ceti class. (6) For a given spectral type the periods of the irregular variables are much shorter than those of the \circ Ceti stars. They may be higher harmonics of the fundamental periods.

Joy has also continued his observations of stars of the T Tauri class, most of which are situated in obscured regions of the Milky Way, sometimes associated with nebulosity. The absorption spectra are of types F and G and indicate low luminosity. The emission spectra are unique in showing bright lines of neutral elements such as iron, magnesium, and calcium, in addition to hydrogen and many ionized elements. Helium is weak or absent, and the forbidden nebular lines are not present.

The H and K lines of ionized calcium are exceedingly strong. In many respects these emission spectra resemble that of the sun's chromosphere.

Numerous individual variable stars of exceptional spectroscopic interest have been under observation during the year. Of these BD $+11^\circ 4673$ (AG Pegasi) is one of the most remarkable. In a fourth report upon this star Merrill finds that the 800-day cycle in the displacements of the hydrogen lines has continued but the amplitude has diminished since 1928. Progressive changes in the spectrum since 1915 include strengthening and widening of bright lines of *H* and *He* I; increasing displacements toward the violet of dark lines, indicating faster outward motions from the star; and a general increase in the ionization of the atmosphere as shown by the lines of *He* I, *He* II, *Fe* I, *Fe* III, *N* II, *N* III, *Si* III, and *Si* IV. The dark bands of *TiO* have gradually grown stronger until their intensities are approximately equal to those in type M1. Thus BD $+11^\circ 4673$ enters the small group of stars with "combination" spectra. If we assume an expanding atmosphere, certain facts suggest that the velocities of atoms increase as they travel outward and that the degree of ionization also increases.

Bands in the spectrum of the N-type variable U Cygni which are especially strong near minimum of light ($\lambda\lambda 6185, 6211$), previously ascribed to the *Ca₂* molecule, have been identified by Sanford as due to the *CaCl* molecule. Thus chlorine seems to be a constituent of the atmosphere of this star. These bands also appear in the spectra of other cool stars of type N.

Joy has found the irregular variable UZ Tauri, previously classified as an old nova, to be a double star with a separation of about $3''.5$. Both components show bright H and K and hydrogen lines and appear to be dwarf Me stars.

An interesting observation by Joy of RW Tauri at time of total eclipse indicates that the brighter B9 star is surrounded by a gaseous shell or ring giving emission lines of *H*, *Mg* II, *Ca* II, and *Fe* II. These lines are displaced 350 km/sec and point to a rapid rate of rotation with a period much shorter than the period of orbital revolution. A twelfth-magnitude companion was discovered at a distance of about 1" from the eclipsing pair.

Joy has also continued his observations of variables of the RV Tauri, SS Cygni, and R Coronae types, and of high-luminosity variables in globular clusters.

MISCELLANEOUS OBSERVATIONS

As a result of the survey of early-type stars with the 10-inch photographic telescope and objective prism, based upon the *H α* line, the discovery of 119 bright-line stars of types B and A has been announced by Merrill, Miss Burwell, and W. C. Miller. For 78 of these stars the types and other spectroscopic data have been determined from slit spectrograms. This investigation also led to the discovery of the bright-line F-type stars to which reference has already been made.

A list of 33 recently discovered stars of types N and S has been published during the year by Merrill, Sanford, and Miss Burwell. Merrill has also studied stars with anomalous spectra combining *TiO* bands and bright lines which require high excitation, and a few early-type stars with spectra resembling those of c stars but believed to be of relatively low absolute magnitude.

Humason has continued his investigation of old novae with a larger dispersion (220 Å/mm) than has heretofore been used. Nine of these objects have been re-observed and confirm the early observations, which showed that in their present

state the old novae are decidedly blue, with spectra corresponding to that of the O- or early B-type stars.

Observations of faint blue stars found by Dr. Zwicky at Palomar have been continued by Humason. In addition, several stars which Zwicky found to have a bright *H α* on objective-prism plates have been investigated. One of these is most probably a faint galactic nova, and the others may be bright-line variable stars.

INTERSTELLAR LINES

The 114-inch Schmidt camera of the coudé spectrograph has been used extensively during the year by Adams in observations of interstellar lines. The high resolving power of the instrument has been particularly valuable in showing the composite structure of the H and K lines in many stars, and in making visible on plates of high sensitivity but coarse grain the other faint lines discovered in recent years. The presence of interstellar lines of neutral iron has been established by observations of the two ground-state lines at $\lambda 3720$ and $\lambda 3860$, which are extremely faint.

The identification by Herzberg of the three lines at $\lambda\lambda 3745$, 3957, and 4232 with lines arising from the *CH* II molecule completes, with the possible exception of one or two doubtful lines, the identification of all the sharp interstellar lines so far discovered. It also provides, through intercomparison of the intensities of $\lambda 4300$ *CH* I and $\lambda 4232$ *CH* II, a means of determining the numbers of *CH* molecules in each state along the line of sight in interstellar space. The observations already made show marked differences in the relative intensities of these lines. For example, in the spectra of the two stars ζ Persei and ξ Persei, which lie but a few degrees apart in the sky and have H and K lines of the

same order of intensity, the ratios of $\lambda 4300$ to $\lambda 4232$ are about 5:1 and 1:5, respectively.

Under the high resolution of the coude spectrograms, complex structure of the H and K lines is found to be the rule rather than the exception. Of the 43 stars investigated, 10 show single interstellar lines and the remaining 33 double or multiple lines. Complex lines are especially numerous in the stars observed in Orion, Ophiuchus, Sagittarius, and Cygnus, and single lines in Perseus and Scorpius. Since the components of the complex lines are doubtless due to individual gaseous clouds and are separated by the relative motions of these clouds in the line of sight, meas-

urements of radial velocity afford a means of identifying the different clouds and determining their extent.

Some individual stars of especial interest are: ν Sagittarii, in which H and K are well marked double lines with the components separated by 0.22 Å; μ Sagittarii, with triple and possibly quadruple components of very unequal intensities; and P Cygni, with two definite components not fully resolved. Three lines due to CH II and one due to CH I are present in the spectrum of P Cygni; and the line $\lambda 4232$ of CH II is visible in ν Sagittarii, the only star of comparatively advanced type of spectrum in which this line has been observed.

GALACTIC NEBULAE

The principal results in the field of galactic nebulae include the definitive interpretation of the spectrum of the Crab nebula (supernova of 1054) by Minkowski, further information concerning the remnant of Kepler's supernova of 1604 by Baade and Minkowski, and the detection of the emerging structure in the expanding shell around Nova Herculis (1934) by Baade. In addition, spectrographic data have been obtained on the filamentary nebula in Cygnus and the inner nebulosity around R Aquarii by Humason, and the distribution of light along a diameter of the typical planetary NGC 6572 has been investigated spectrophotometrically by Seyfert.

EXPANDING SHELL AROUND NOVA HERCULIS (1934)

Direct photographs obtained by Baade in the spring of 1942 indicate that the surface brightness has declined much faster during the past two years than can be accounted for on the assumption of constant total brightness and increasing size of disk.

A star is now easily seen at the center, and the true structure of the shell, apparently that of an elliptical ring nebula, is beginning to emerge. This interpretation of the structure is confirmed by a large-scale spectrum of the nebulosity obtained on June 8, 1942, by Humason and Baade. The N I and N II lines appear as elliptical rings such as would be expected from an expanding shell of finite thickness.

SPECTROGRAPHIC STUDY OF THE CRAB NEBULA REMNANT OF THE SUPER- NOVA OF 1054

The spectrographic study of the Crab nebula has been concluded by Minkowski after an extension of the observations into the red and the ultraviolet. The line emission spectrum of the filaments contains lines of H, He I, He II, [N II], [O I], [O II], [O III], and [S II]. The H lines are relatively faint, probably owing to low abundance of hydrogen. The high intensity of the filaments in the red is due to the [N II] and the unusually intense [S II] lines. The spectrum of the diffuse

nebulousity forming the main mass is continuous except for a faint discontinuity at the Balmer limit. Practically the entire energy emitted by the nebula is contained in the continuous spectrum, whose intensity distribution deviates from that of a black body, the color temperature being about 8400° at $\lambda 4500$, and 6700° at $\lambda 6000$.

In the absence of absorption in the nebula, the continuous spectrum cannot be due to scattering and must be a true emission spectrum. The only physically justified assumption is that the continuous spectrum is produced by free-free and free-bound transitions of electrons in the very highly ionized gas. On this assumption, the observed intensity distribution in the continuous spectrum finds a satisfactory explanation. The electron density of the diffuse mass is of the order 10^8 cm^{-3} , the electron temperature of the order $50,000^\circ$, the mass about 15 solar masses, and the hydrogen abundance probably low. The central star has a temperature of the order of $500,000^\circ$, a radius of 0.020 solar radius, and a total luminosity of 30,000 solar units. These results as a whole indicate that before their outbreak, supernovae of type I are massive stars of low hydrogen abundance. During the outbreak, the star ejects the greater part of its mass and begins to develop into a white dwarf. The present high temperature and high luminosity of the central star of the Crab nebula indicate that this stellar remnant of the supernova of 1054 has not yet finished the transformation into the degenerate state.

NEBULOSITY AROUND NOVA OPHIUCHI (1604)

Long-exposure photographs in the red, obtained by Baade, show that the fan-shaped mass he discovered last year is only a part of the nebulousity surrounding

the former supernova, and that faint wisps are scattered over a field about $80''$ in diameter. Evidently the obscuration in front of the nebula is not only very heavy, as was pointed out in last year's report, but also quite variable over the field.

The spectrum of the nebulousity has been observed in the red by Minkowski. The combination of a plane grating (400 lines per mm) with a solid Schmidt camera, $f/0.65$, giving a dispersion of 400 Å/mm, has shown itself very useful for this purpose. The spectrum of the nebulousity consists of the lines $[O \text{ III}] \lambda 5007$, $[O \text{ I}] \lambda 6300$, $[N \text{ II}] \lambda \lambda 6548, 6584$, $H\alpha$, and $[S \text{ II}] \lambda 6731$. The spectrum is very similar to that of the filaments of the Crab nebula, especially as regards the low intensity of $H\alpha$ relative to the $[N \text{ II}]$ lines. The intensity of $[O \text{ III}] \lambda 5007$, however, is much less than in the Crab nebula. This is evidently due to heavy space reddening, and a color excess of about 2 magnitudes is suggested. The radial velocity is -200 km/sec at the (north following) tip of the fan-shaped nebulousity and probably about -260 km/sec at the (south preceding) base. The velocity is too high to admit any interpretation other than that the fan-shaped nebulousity is part of an expanding nebula, the center of expansion being situated closer to the base than to the tip.

DISTRIBUTION OF LIGHT IN NGC 6572

From a spectrophotometric study of the distribution of light along a diameter of the planetary NGC 6572, Seyfert has found that the luminosity gradients in the emission lines N_1 , N_2 , $\lambda 4471$, $\lambda 4363$, $\lambda 3869$, and the hydrogen lines are remarkably similar. The $O \text{ II}$ doublet, $\lambda 3727$, however, gives an image 20 to 30 per cent larger than the mean of the other monochromatic images that have been investigated. The results are consistent with Berman's

earlier investigations of monochromatic images of the nebula.

MISCELLANEOUS

Humason and Baade have succeeded in obtaining a number of long-exposure spec-

trograms of faint wisps of nebulosity within the great Cygnus Loop for the purpose of investigating expansion in the line of sight. Humason has also obtained additional spectra of the inner emission nebulosity around the variable star R Aquarii.

EXTRAGALACTIC NEBULAE

The principal results in the study of extragalactic nebulae are the completion of investigations of the direction of rotation in spirals by Hubble, and of nuclear emission in spirals by Seyfert. In addition Baade has identified an eclipsing binary and a normal Cepheid with the unusual period of 146 days in IC 1613, and Hubble and Humason have made considerable progress in the observing program which will eventually lead to a general catalogue of the fundamental data furnished by nebular spectra.

DIRECTION OF ROTATION OF SPIRALS

Hubble has found that in 15 spirals for which the necessary data are available, the dissymmetry of obscuration combined with the character of the spiral pattern is definitely correlated with the sense of the spectrographic rotation. On the assumption that the tilt is indicated by the dissymmetry of obscuration, all 15 nebulae are rotating in the same direction with respect to the spiral patterns.

In 4 spirals, NGC 3190, 4216, 4258, and 4527, the actual direction is determined by dark lanes which, because they are silhouetted against the nuclear bulges, unambiguously identify the nearer sides of the nebulae. In these nebulae, the arms are trailing behind the nuclear regions. The results are the basis for the working hypothesis that the arms are trailing in all spirals, and that the greater obscuration identifies the nearer side of the projected image of a nebula.

NUCLEAR EMISSION IN SPIRALS

Seyfert has continued his investigations of nuclear emission in spirals with especial emphasis on NGC 1068, 3516, and 4151. The emission lines and their relative intensities in these nebulae (as well as NGC 1275 and 4051) show a general similarity to the lines in the planetary NGC 7027. The lines are superposed on G-type continuous spectra in which the intensity distributions correspond to temperatures of 5250° for NGC 1068 and 3516, and 4750° for NGC 4151. The ratios of light in the emission lines to the total luminosities (emissions plus continua) in the photographic region are about 13, 5, and 20 per cent for NGC 1068, 3516, and 4151, respectively.

The line contours in NGC 1068 fall into two main groups, with line widths ranging from 2400 km/sec for $\lambda 3869$ and $\lambda 3968$ of [Ne III] to 3600 km/sec for $\lambda 6717$ and $\lambda 6731$ of [S II]. The four lines N1, N2, H β , and $\lambda 3869$ have absorption cores, and considerable evidence, including wave lengths and equivalent widths, suggests that the apparent central reversals may be due to superposed absorption lines arising from the G-type continuum.

In NGC 3516, the hydrogen lines are extremely broad, shallow bands ($> 100 \text{ \AA}$), whereas N1 and N2 are relatively narrow. In NGC 4151, the contours of the forbidden lines and of the cores of the hydrogen lines are closely similar. They are about 1000 km/sec wide and show pro-

nounced asymmetry. The bright cores of the hydrogen lines $H\alpha$ to $H\delta$ are superposed on fainter wings, each about 7500 km/sec wide. The spiral NGC 7469 (for which Dr. Mayall first reported an emission spectrum) has hydrogen lines with wide wings resembling those observed in NGC 4151.

SPECTRA OF NEBULAE

Spectra of 82 nebulae, 60 of which had been previously unobserved, were obtained during the year by Hubble and Humason. The Mount Wilson collection now includes spectra of 370 nebulae out of the total of 440 observed at all stations. Most of the spectra are on a small scale, but those of 50 nebulae are on an intermediate scale, and those of 4 nebulae on a sufficiently large scale (65 A/mm and larger) to permit the study of line contours.

LABORATORY INVESTIGATIONS

RARE-EARTH SPECTRA

Further studies of rare-earth spectra by A. S. King have dealt with gadolinium and dysprosium, and a beginning has been made upon terbium. The completion of the temperature classification of Gd lines involved additional work on the ultraviolet spectrum and improvement of the data for other regions. The final list, from $\lambda 2135$ to $\lambda 10670$, contains 5732 lines, extending the spectra of Gd I and Gd II to lines of low intensity. At wave lengths shorter than $\lambda 2700$, where very few lines had previously been measured, the lines of Gd III are prominent. The strongest of these, some from such low atomic levels as to appear in the arc spectrum, are listed. A comparison with the solar spectrum shows that many low-level lines of Gd II, present in the furnace spectrum, coincide with unidentified solar lines. If the probability

VARIABLES IN IC 1613

Baade has obtained a spectrum of a Cepheid in IC 1613 with the exceptionally long period of 146.35 days. The star was near maximum ($m_{pg}=17.5$). The spectral type was K2 (based on the intensities of Ca $\lambda 4227$ and the Sr pair, $\lambda\lambda 4215$ and 4077). The supergiant character of the star is indicated by the great strength of the hydrogen lines. The data remove the last doubts that Cepheids with periods up to 150 days (and perhaps 200 days) do occur. Periods longer than 50 days, however, are extremely rare.

Another interesting variable in IC 1613 has proved to be an eclipsing binary with a period of 3.775 days. Both the color and the density (derived from the photometric orbit) indicate that the main component is an early B-type star. The absolute magnitude of the system is -2.6 .

that these lines occur in the sun is confirmed by the term analysis being made by Albertson and Russell, a considerable increase in the number of Gd solar lines over those identified in the *Revised Rowland* table of solar wave lengths will result. No evidence of Gd I in the sun has thus far been found.

Dr. Russell has extended the analysis of the gadolinium arc spectrum and has derived an ionization potential of 6.16 volts. Further analysis is in progress.

The spectrum of Dy has been examined from $\lambda 3150$ to $\lambda 6800$, chief attention being given to the lines of Dy II and their classification by means of the furnace spectrum. As in the case of Gd , agreement with solar lines is found for many of the strong low-level lines of Dy II, as well as for the few identified in the *Revised Rowland*. The Dy spectrum has a group of very strong

low-temperature lines in the violet which reverse easily in the furnace—a type unusual in rare-earth spectra. The strongest of these lines, when not masked, are identified in the *Revised Rowland* with faint solar lines, and, before the furnace spectra were available, were ascribed to *Dy* II. They are now shown to be due to *Dy* I, this being the second rare earth whose neutral lines have been observed in the sun. Those of a third element, europium, are found only in the sunspot spectrum.

CALCIUM OXIDE

A group of green and orange bands, present in many red stars, and tentatively ascribed to calcium oxide, has been examined in the electric furnace by A. S. King. The oxide origin was confirmed when the bands appeared with high intensity in the furnace spectrum of calcium with oxygen passing over the metal, but were absent when calcium was vaporized in vacuum at the same temperature.

ABUNDANCE OF IRON IN THE SUN

A value for the abundance of neutral iron atoms in the sun has been derived by R. B. King. Solar equivalent widths from Allen's tables and the Utrecht Atlas in conjunction with absolute *f*-values obtained recently in the laboratory were utilized. Twenty-three strong iron lines, on the square root, or damping, portion of the solar curve of growth, for which absolute *f*-values are available were used. A damping constant of 10 times the classic value and an excitation temperature of 4400° were assumed in making the computations. The total number of neutral iron atoms per square centimeter was found to be 4.3×10^{18} .

The cause for small but apparently real systematic differences between the results for abundance given by lines of different

multiplets is as yet obscure, since several factors may be involved. Laboratory investigations by Minkowski and R. B. King have shown that the differences cannot be due to pressure broadening alone, since no similar differences are found for these lines broadened by atmospheric pressure at 2890° in the furnace. The suggestion is made that under solar conditions broadening due to "natural" widths of the lines is not negligible. An extension of the laboratory *f*-values for *Fe* to lines of higher level which has been in progress may aid in settling this question.

RELATIVE *f*-VALUES

The work on relative *f*-values for *V* I, *Ni* I, and the higher-level lines of *Fe* I has been continued. In vanadium almost all lines of temperature classes I–IV are observed in absorption at a furnace temperature of 3000° C. For the present, however, it has been decided to limit the observations to lines of classes I–III in the astrophysical region of the spectrum. Measurements on a large part of these lines are complete.

RULING MACHINES

Some minute errors of the accidental type in the smaller ruling machine have been traced by Babcock and Prall to the thrust bearing of the screw. To bring these under control the plan has been devised of subjecting the bearing to a definite, constant load, large as compared with the operating stresses, and applied directly to the screw itself. The mechanical parts needed to test this method are nearly completed.

The larger machine, with its capacity for ruling gratings of very great size, for example metallic gratings from which replicas can be made for use as objective

gratings, has been modified to admit of spacings between 600 and 1000 to the inch and lines up to 18 inches long. Because of the coarse spacing, remarkable concentration of the diffracted light is possible. Numerous small rulings of excellent quality have been made, and the problem of

producing a large ruling surface with suitable properties is being investigated. Evaporated and electroplated metallic films, alloys of soft metals, wax, and plastics have been tested, with the result thus far that a lead-tin alloy seems to be best adapted for the purpose.

CONSTRUCTION AND MAINTENANCE

DESIGN AND INSTRUMENT SHOP

About 70 per cent of the time of the department of engineering and design during the past year and 55 per cent of the time of the instrument shop have been devoted to the design and construction of apparatus and instruments, usually experimental, for military purposes. The instrument and optical shops have cooperated closely in this work.

The mounting of the new 10-inch photovisual telescope has been completed, and this instrument should soon be in operation. Other equipment which has been designed and partially constructed includes a small prime-focus spectrograph, a projection measuring machine, and the automatic microphotometer planned by Whitford and O. C. Wilson.

E. C. Nichols, assisted by H. S. Kinney, has continued in charge of the department of design, and Albert McIntire of the instrument shop.

OPTICAL SHOP

A very large part of the work of the optical shop, which has been expanded to include a part of an adjoining building, has consisted in the development of methods of manufacture and testing of optics

for military use. D. O. Hendrix has devoted his entire time to this work, and John Dalton has been completing the figuring of the three-component objective of the 10-inch photovisual telescope.

BUILDINGS AND GROUNDS

Both on Mount Wilson and in Pasadena, construction has been limited to repairs and general maintenance except for such changes as have been necessitated by the war projects in progress. Several buildings have been repainted and the paving of the road extending through the Observatory property on Mount Wilson has been completed. A wire fence, enclosing the laboratory, powerhouse, and living quarters on the southern side of the mountain top but allowing the public access to the main telescope buildings, has added greatly to the comfort of the observers and others living on the mountain. This work has been in charge of A. N. Beebe, superintendent of construction.

A large part of the telephone line, including many poles, has been replaced during the year by Sidney Jones, engineer, and Kenneth de Huff, assistant engineer. Connections with this line have been afforded to the U. S. Signal Corps and other military observers on Mount Wilson.

THE LIBRARY

The library now contains 14,857 volumes, together with large collections of pamphlets and lantern slides. During the year

298 volumes were added, 56 by purchase, 43 by gift, and 199 by binding. From the 200 observatories and research institutions

whose publications generally come to the Observatory, very little material has been received because of the war. The number

of periodicals received during the year has dropped from 140 to 87; 29 of these are gifts or exchanges.

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SPECIAL PROJECTS: ASTRONOMY

DIRK BROUWER, Yale University Observatory, New Haven, Connecticut. *Program for the determination of systematic corrections to fundamental catalogues from observations of minor planets.* (For previous report see Year Book No. 40.)

The number of plates obtained for this program during the year was 569, of which 181 were secured at the Yale Southern Station in Johannesburg, 227 at New Haven, and 161 at the Allegheny Observatory of the University of Pittsburgh. This number does not include the observations obtained at the Leiden Observatory. The work of that observatory was interrupted for a few months in the summer of 1940, but resumed in August of that year. Reductions of the Leiden observations for the year 1940 were received in manuscript. No report for the year 1941 has been received beyond word that the work was being continued.

The measurement of plates at Yale Observatory has been continued at an increased rate, the number of plates measured during the year being 751. This increase was made possible primarily by the addition to our staff of Dr. Gustav Land. Both Dr. Land and Miss Ruth J. Huff devoted full time to this part of the work.

Reductions of the measurements have been made under the supervision of Miss Louise F. Jenkins, but no attempt has been made to keep in step with the measurements. Greater concentration on the reductions will soon become desirable.

The calculation of the perturbations of 15 asteroids for 24 years, 1924 to 1948, was completed, and the numerical integration of 5 orbits was extended backward to the year 1924. Of the entire first-integration program of 15 planets, less than 40

per cent remains to be done. A large part of the uncompleted work concerns the planets Ceres, Pallas, Juno, and Vesta. For these planets the Astronomisches Rechen-Institut in Berlin furnished annually extensive ephemerides of a quality that was more than sufficient for the observational requirements. On this account work on these 4 orbits could be delayed until the orbits of the other planets on the program had been fully determined. During the past year first integrations and orbit corrections for Ceres and Pallas were made at Yale Observatory by Dr. Hans G. Hertz and Dr. Brouwer. Dr. Paul Herget, of the Cincinnati Observatory, gave his valued cooperation in this part of the program, contributing numerical integrations and orbit corrections for the planets Juno and Vesta. The orbits of these 4 planets are now ready for accurate integrations over the 24-year period by the Thomas J. Watson Astronomical Computing Bureau.

Owing to the progress made with the numerical integration of the orbits, the time has now arrived when useful comparisons of the orbits with observations in numerous oppositions can be made, preliminary to further improvement of the orbits. For the planet (7) Iris such work was undertaken by Mr. Oscar T. Schultz, of the U. S. Naval Observatory. He succeeded in representing the observations in eight oppositions with a highly satisfactory degree of accuracy. A similar discussion of the orbit of (57) Mnemosyne by Dr. Land is now in progress.

S. A. MITCHELL, University of Virginia, Charlottesville, Virginia. *Astronomical studies at the Leander McCormick Observatory*. (For previous reports see Year Books Nos. 38 to 40.)

For a hundred years, astronomers have been on a constant search for faint or invisible companions of bright stars. In 1844, in order to explain the variable proper motions of Sirius and Procyon, Bessel predicted the presence of a companion to each of these bright stars. In 1861, Alvan G. Clark discovered the companion of Sirius, in itself one of the most interesting stars in the sky, though the companion is 10,000 times fainter than the primary. In 1896, Schaeberle discovered the companion of Procyon. In a similar manner, through the variable proper motion of an 11th-magnitude star on the McCormick parallax program, Dr. D. Reuyl found that the star Ross 614 is a double, the first star of the Sirius type to be discovered by photographic processes. Ross 614 has been followed for several years, and the period is about 15 years. The companion has not been seen visually. Dr. Reuyl has found a second star with variable proper motion, Cincinnati 1244. The masses of the invisible companions must be less than one-tenth the mass of the sun. These stars are both of dwarf M type with emission lines. It appears that stars of this type have a high probability of being double.

Duplicity has been found directly from McCormick photographs for the two stars Wolf 424 and BD $+19^{\circ}5116$. The photographs reveal that the former is in fairly rapid motion, the distance having decreased from $0''.8$ to $0''.3$ in about one year. In view of the fact that the scale of the McCormick photographs is $1 \text{ mm} = 20''$ of arc, the centers of the components of Wolf 424 are now separated by only 0.015 millimeter. This is far too small a separation to permit measurement directly,

but none the less the exquisite definition of the McCormick refractor permits the detection and measurement of the elliptical character of the images of Wolf 424 as compared with the circular images of nearby stars of the same magnitude. For all cases in which duplicity has been established, an attempt is being made to determine the masses.

Wolf 630, the visual binary of shortest known period, 1.8 years, and of angular separation $0''.2$, is being followed photographically by Dr. Reuyl. The feature of particular interest in this work is the fact that preliminary results of the measures seem to indicate inequality of the masses in spite of the fact that the photovisual magnitudes of the components are equal.

Another McCormick research on an interesting double star has been conducted by Dr. Reuyl with the collaboration of Dr. Erik Holmberg, of the Lund Observatory, Sweden. By the use of coarse wire grating placed before the object glass, Hertzprung many years ago showed that for double stars of unequal but bright components of fair angular separation, by the use of a grating with appropriate widths of wires and interspaces, the first-order spectra of the principal star could be made equal in magnitude to that of the fainter companion. Hertzprung with the Potsdam and Johannesburg refractors, and Reuyl with the McCormick refractor have obtained photographs extending over many years for the double star 70 Ophiuchi. The measures of the McCormick grating photographs together with those on the regular parallax series combined with the measures of the Potsdam and Johannesburg photographs were compared with Strand's orbit. These comparisons seemed

to give fairly positive information that 70 Ophiuchi is accompanied by a third invisible star. The assumption of a circular orbit about the A or B component of 70 Ophiuchi, together with the period of 18 years, seems to indicate the smallest mass yet known for any stellar object, namely 0.01 to 0.02 of the mass of the sun.

Trigonometric parallaxes continue to be the chief research at the McCormick Observatory. Through the kindness of Dr. Kuiper, of Yerkes and McDonald observatories, a number of stars with large spectroscopic parallaxes have been put on the McCormick program. For many of these stars of M type, trigonometric parallaxes have been derived at McCormick.

The second proper-motion program of the McCormick Observatory is nearing completion. The measures of both the motions and the magnitudes of the 11,300 stars involved have been finished and the spectra for about 7500 of the stars have been determined. The proper motions in the first publication were reduced to the system of the General Catalogue. The motions of all stars in both the first and second investigations have now been reduced to the FK3 system. The motions of the more than 29,000 faint stars in the two investigations will be discussed independently and in combined solutions.

The Observatory was represented at the Symposium on Galactic Structure held May 2-3, 1941, under the auspices of the New York Academy of Science by Dr. Emma T. R. Williams, who contributed a discussion of mean parallaxes derived from peculiar motion.

Dr. A. N. Vyssotsky represented the Observatory at the Inter-American Astrophysical Conference held February 17-25, 1942, to celebrate the inauguration of the National Astrophysical Observatory at Tonanzintla, Mexico. He reported on the spectroscopic work in progress with the

10-inch Cooke prismatic camera, and pointed out, among other things, the possibilities for the discovery of stars with peculiar spectra. Thus, to date he has picked up accidentally 9 new S-type stars and 4 new planetary nebulae. The total number of new dwarf M stars found spectroscopically on McCormick plates has now reached more than 50.

Measurement of proper motions of the Cepheids is progressing in satisfactory manner. As indicated in earlier Year Books, this research is being conducted in cooperation with the Mount Wilson Observatory. The measures for the 90 regions already finished by Dr. Mitchell show an average internal probable error of 0''.0022 for the proper motion of the Cepheid referred to about 16 surrounding stars.

During the past year astronomers from other institutions have been in residence at McCormick in order to make use of the spectra of faint stars obtained with the 10-inch Cooke refractor. Father W. J. Miller, a graduate student of Harvard Observatory, spent six weeks in classifying the spectra of more than 2000 stars and in comparing his system of classification with that of the southern part of the Henry Draper Catalogue. Similarly, Dr. A. Marguerite Risley, of Randolph-Macon Woman's College, classified the spectra of 4000 stars. In each case, the spectra are to be used in connection with the statistical investigations of the structure of the Milky Way in cooperation with Harvard College Observatory.

Another contribution by means of the 10-inch Cooke telescope is the set of 332 photovisual sequences distributed uniformly over the sky from -15° to $+75^\circ$ declination. These were derived from equal-altitude polar comparisons by Mr. C. A. Wirtanen, and show very satisfactory agreement with the I Pv system.

In the summer of 1941, while in residence at the Mount Wilson Observatory, Dr. Mitchell by means of the 60-inch reflector obtained the spectra of about 100 A and K stars of the 10th magnitude for the determination of their radial velocities. The stars for this program were selected

from the second McCormick proper-motion investigation.

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GEOPHYSICAL LABORATORY

Washington, District of Columbia

L. H. ADAMS, *Director*

In the summer of 1941 the first step was taken toward setting up a comprehensive program of defense research centered at the Geophysical Laboratory and under the auspices of the National Defense Research Committee of the Office of Scientific Research and Development. Previously, different members of the scientific staff had accepted problems presented for solution by various governmental agencies, but the regular scientific work was proceeding without major disturbance. The new undertaking was of a magnitude which appeared to require all the Laboratory's facilities and personnel. At the start some time was required for collecting information from military and other sources and for delineating the various lines of research and development. Several of the staff members turned immediately to the new assignment; others proceeded as rapidly as possible to round out those parts of the current researches that were nearing completion, preparatory to laying their customary work aside for the duration of the emergency. During this transition period there was opportunity to put the finishing touches on several investigations and to prepare them for publication. It is fortunate that without hindering the preparations for our present program of developing new devices for offense and defense, the results of a number of researches could be collected and published, and thus even in a small way the continuity of fundamental research in geophysics could be preserved for a while.

Shortly after the declaration of war, all resources of the Laboratory were applied toward war work. With few exceptions,

staff members are now occupied with various parts of the war program undertaken by the Laboratory. These exceptions include one member who is filling an administrative position in a unit of the NDRC, one member on leave of absence who is a civilian employee of the War Department, two on leave of absence who are civilian employees of the Navy Department, and one on leave of absence who is managing a large optical glass plant. Despite the urgent need at the Laboratory for experienced investigators, it appeared that these persons were rather uniquely qualified for their respective special tasks, and it was judged that in these capacities their services would contribute best to the war effort. The regular staff has been supplemented by about thirty temporary employees, including physicists, mathematicians, chemists, technicians, and stenographers.

Although almost all the work has been on a single unified program in the interest of the war effort, two or three smaller assignments have been accepted and carried forward under contract. For the main undertaking the Geophysical Laboratory functions not only in the performance of a contract for research and development between the Institution and the OSRD, according to which the Institution is reimbursed for the cost of new equipment and additional personnel; the Laboratory is also the focus of a still larger program involving a dozen or more contracts with universities, institutions, and commercial organizations. The Director of the Laboratory is the chairman of a unit in the NDRC, and by virtue of this governmental appointment is primarily responsible for

initiating and carrying forward the program as a whole. An office of this governmental unit is maintained at the Geophysical Laboratory, and for the handling of the official administrative business two full-time Civil Service employees are stationed there.

The following is a summary of the regular work completed and published during the past twelve months. Inasmuch as most of the investigations have been referred to in previous annual reports, it will perhaps suffice merely to present the abstracts of individual papers.

SUMMARY OF PUBLISHED WORK

- (1051) Bradleyite, a new mineral, sodium phosphate—magnesium carbonate. Joseph J. Fahey. (With X-ray analysis by George Tunell.) *Amer. Mineralogist*, vol. 26, pp. 646–650 (1941).

A new anisotropic fine-grained mineral, associated with shortite and carbonaceous clay, was found in the drill core of the John Hay Jr. Well No. 1 in Sweetwater County, Wyoming, at a depth of 1342 feet 10 inches, by Mr. Fahey, of the Geological Survey, U. S. Department of the Interior, Washington, D. C. It has been named bradleyite in honor of Dr. W. H. Bradley, of the Geological Survey. Chemical analysis shows that the formula is $\text{Na}_3\text{PO}_4 \cdot \text{MgCO}_3$. X-ray powder diffraction photographs of bradleyite were made by Dr. Tunell, of the Geophysical Laboratory, with filtered copper K radiation and show that it does not contain MgCO_3 in the form of magnesite. The spacings and intensities of the X-ray powder photograph of bradleyite are tabulated to aid in its future identification.

- (1052) Introduction to symposium on "Reactions and equilibria in chemical systems under high pressure" (*Amer. Chem. Soc.*). R. E. Gibson. *Chem. Revs.*, vol. 29, pp. 439–445 (1941).

From a detached thermodynamic point of view it may seem surprising that studies of the effects of temperature and of composition variations should so far have outrun studies of the effects of pressure, because the three variables—pressure, temperature, and composition—are of coordinate thermodynamic importance in determining the state of a chemical system. The purpose of this sym-

posium is to take cognizance of the fact that interest in the behavior of chemical systems under pressure changes has increased in the past decade, and to consider some recent advances that have been made. By way of introduction to the papers given in the symposium, attention is called to six general fields in the study of material systems under high pressure that are of interest to chemists, as follows: (1) the displacement of equilibria in homogeneous systems under high pressure; (2) the displacement of equilibria in heterogeneous systems; (3) acceleration or retardation of chemical reactions by pressure; (4) new phenomena; (5) knowledge of the behavior of naturally occurring substances under extreme conditions; (6) new methods of attacking old problems.

In order to illustrate the place of the various types of high-pressure investigation in the general scheme of physical chemistry and to answer the still frequent question "What do P—V—T measurements have to do with chemistry?" a chart showing the interrelations among the various activities is given.

- (1053) Equilibrium in heterogeneous systems at high temperatures and pressures. L. H. Adams. Symposium on "Reactions and equilibria in chemical systems under high pressure" (*Amer. Chem. Soc.*). *Chem. Revs.*, vol. 29, pp. 447–459 (1941).

Following a summary of the principles involved in chemical equilibria, there is given a brief discussion of apparatus and experimental procedure for investigations in this field. Special attention is paid to systems that include a solid phase. The effects of pressure and of temperature are considered separately

and in combination. A résumé is presented of certain experimental results obtained at pressures extending to several thousand atmospheres and at temperatures exceeding 1000° C. Reference is made to the application of these results to manufacturing processes and also to volcanology and other branches of geophysics.

- (1054) Radioactivity of ocean sediments. IV: The radium content of sediments of the Cayman Trough. C. S. Piggot and Wm. D. Urry. *Amer. Jour. Sci.*, vol. 240, pp. 1-12 (1942).

The radioelements in the uppermost layers of the sediments at the bottom of the ocean are not in equilibrium, and a study of the relations that exist in material of uniform character, lying under very deep water, is of fundamental importance in any interpretation of more complex sediments, such as are produced under areas of intermittent glaciation or other disturbing influences. Therefore material from a great ocean deep situated in middle latitudes is of special value. The Cayman Trough, lying south of Cuba, and including the Bartlett Deep, is a peculiarly satisfactory location for such studies. Here the water is almost stationary and the biologic environment has remained quite uniform for a long time. Among the many radioactive elements, uranium, ionium, and radium have sufficiently long lives to be of special importance in such studies. A history of these three elements is reflected in the variation of the radium content of ocean sediments with depth below the ocean floor. Measurements of this variation demonstrate that the concentrations of uranium, ionium, and radium at any given time are established by the usual laws of radioactivity governing the growth and decay of radioelements in a system that is not in radioactive equilibrium. The experimental results must be adjusted to the condition of the sample in the undisturbed sediment. This requires a knowledge of the history of the specimens, from the time when the sediment was taken by the core sampler to the time at which the specimens were analyzed. The relation between radium

content and depth in a given ocean sediment promises a method of determining the rate of accumulation of the deposit at that place.

- (1055) Melting and transformation temperatures of mineral and allied substances. F. C. Kracek. Section 11 of Special Papers No. 36, *Geol. Soc. Amer.*, "Handbook of physical constants," ed. Francis Birch, pp. 139-174 (1942).

This is a critical compilation of melting points and other characteristic temperatures for minerals and mineral-like artificial compounds and other substances which may be of interest to the worker in geological sciences. Data are given for the individual compounds, and for binary and higher mixtures of such compounds, so far as they are known. The material is arranged under the following headings: elements; oxides; hydrous and hydrated oxides; binary aluminates; binary borates; binary oxide systems; three or more oxides (except SiO_2); binary silicates; ternary and higher silicate systems (except systems with Al_2O_3 and B_2O_3); aluminosilicates; borosilicates; miscellaneous systems containing silicates; hydrothermal alteration of silicates and other minerals; carbonates; sulfates; oxygen salts; haloids; sulfide-type minerals; ternary sulfides. The aim in compiling the tables has been to describe the known thermal reactions of the compounds and the systems briefly, but in enough detail to be of use to an investigator not only in the laboratory but also in the field, where extensive reference books are usually not available.

- (1056) Effect of pressure on phase equilibria in binary condensed systems. R. E. Gibson. Section 13 of Special Papers No. 36, *Geol. Soc. Amer.*, "Handbook of physical constants," ed. Francis Birch, pp. 187-202 (1942).

Although very few data on the effect of pressure on binary systems of direct geological interest are available, a variety of chemical systems have been studied experimentally over ranges of pressure and temperature, and these systems are sufficiently varied to give a general picture of the types of effect that may

be expected. The compilation is not exhaustive, but an attempt has been made to include all the different types of behavior that have been observed, and a list of references is appended with a notation of the contents of the papers cited. The following headings show the scope of the compilation: I. Binary condensed systems containing water: (*a*) effects of relatively low pressures on the solubility of salts in water at constant temperature; (*b*) effects of high pressures on the solubility of solids in water; (*c*) effect of pressure on the temperature of the incongruent melting of hydrates. II. Binary condensed systems composed of organic compounds: (*a*) pressure—solubility relations at constant temperature; (*b*) effect of pressure on the eutectic temperature and composition; (*c*) miscellaneous examples.

- (1057) Temperature — pressure — volume and phase relations of water. Roy W. Goranson. Section 14 of Special Papers No. 36, Geol. Soc. Amer., "Handbook of physical constants," ed. Francis Birch, pp. 203-212 (1942).

In this compilation are presented tables of the most probable values for the specific volume of water in various forms over a considerable range of temperature and at pressures up to 1200 bars. Included also is information on: the volume change associated with various transformation points; the heats of vaporization and heat capacity of water; the equilibrium pressures and temperatures at the several triple points; and data for the various equilibrium curves including melting curves.

- (1058) Heat capacity; heat of fusion. Roy W. Goranson. Section 16 of Special Papers No. 36, Geol. Soc. Amer., "Handbook of physical constants," ed. Francis Birch, pp. 223-242 (1942).

The existing information on the heat capacity of minerals and rocks and the heats of fusion and transformation is tabulated in convenient form. The heat capacities are calculated in terms of the true or instantaneous values over a range of temperatures ex-

tending in many instances from -200 to 1200°C . Full literature references are given.

- (1059) Radioactivity of ocean sediments. V: Concentrations of the radio-elements and their significance in Red clay. Wm. D. Urry and C. S. Piggot. Amer. Jour. Sci., vol. 240, pp. 93-103 (1942).

The relationship between the radioelements uranium, ionium, and radium in those deep-sea deposits known as "Red clay" is similar to that previously described for the calcareous sediments of the ocean. The Red clay, represented by a core 246 cm long, is distinguished from the calcareous sediments by a very rapid decrease in the radium content just below the surface of the ocean bottom, and by the attainment of the final equilibrium between the above three radioelements in the bottom quarter of the core, which signifies a very slow deposition as compared with that of the calcareous deposits. The radium content at equilibrium with the uranium is only 7 per cent of that near the surface of this Red clay deposit. The high surface concentrations of radium and ionium, particularly in Red clay, are therefore only transient phenomena, produced by some unknown mechanism which concentrates these elements, relative to the uranium content, during the deposition of the sediment.

- (1060) Methods and instruments used in mineralogy. F. E. Wright. Amer. Mineralogist, vol. 27, pp. 145-154 (1942).

This paper was delivered before a joint session of the Mineralogical and Geological Societies of America as the address of the retiring president of the Mineralogical Society. It considers briefly a few of the methods and instruments now in use by mineralogists in determining the physical, crystallographical, and chemical properties of minerals. Experience has shown that in experimental work the introduction of a new method or a new instrument may enable the observer to explore fields heretofore inaccessible for lack of the proper weapons of attack. In present wartime surroundings this condition is especially evident, as is also the importance of adequate

supplies of the instruments of warfare and of new methods and weapons of defense and of offense.

In particular, the paper discusses three tools useful to mineralogy—the reflecting goniometer, the petrographic microscope, and X-ray apparatus—for the purpose of illustrating how progress in mineralogy has been dependent on the availability of suitable methods and instruments of attack; and how an instrument useful in one branch of science may prove to be equally serviceable in another field, if properly adapted to meet the conditions imposed in the new field.

(1061) The radio-elements in non-equilibrium systems. Wm. D. Urry. *Amer. Jour. Sci.*, vol. 240, pp. 426-436 (1942).

In an isolated system in which the radio-elements are not in equilibrium, the relative amounts of the members of a radioactive series are established by time only. Such a system exists in the uppermost sediments of the ocean bottom, and the relative amounts of uranium, ionium, and radium have been determined in a number of core samples of such ocean-bottom deposits. In order to assign time intervals to these sediments, an equation was needed, but the general equation could not be found in the literature, although special cases for simple initial conditions have been treated. The general equation has now been developed. Its derivation assumes no particular initial amounts of the various members of a radioactive series.

(1062) The system $\text{CaO}-\text{FeO}-\text{Al}_2\text{O}_3-\text{SiO}_2$. I: Results of quenching experiments on five joins. J. F. Schairer. *Jour. Amer. Ceram. Soc.*, vol. 25, pp. 241-274 (1942).

A study of the quaternary system $\text{CaO}-\text{FeO}-\text{Al}_2\text{O}_3-\text{SiO}_2$ was undertaken in order to obtain information about the mutual melting relations of pyroxenes, pyroxenoids, olivines, and melilites—four important groups of rock-forming minerals—and to acquire specific knowledge of their chemical compositions. Each of these mineral groups involves extensive solid solutions.

In this preliminary paper, liquidus data are presented for five planes within a regular tetrahedron used to represent the phase relations in the quaternary system. These five planes were chosen to explore that portion of the tetrahedron containing compositions of interest to igneous petrology.

The results of quenching experiments on 216 separate compositions are given. Liquidus data are complete for five joins through the tetrahedron: SiO_2 —anorthite— FeO , anorthite— Al_2O_3 — FeO , CaSiO_3 —anorthite— FeO , gehlenite—anorthite— FeO , and CaSiO_3 —gehlenite— FeO .

Although data are given for only five joins, it has been shown how these data indicate within approximate limits the temperatures and compositions of eleven quaternary invariant points and show the direction of change of composition of the liquid phase during crystallization in a large portion of the tetrahedron.

An equilibrium diagram for the ternary system $\text{FeO}-\text{Al}_2\text{O}_3-\text{SiO}_2$ is given, but the data on which it is based will be published in a separate paper.

Much information on the coexistence of solid phases is presented, and the approximate composition of the liquid phase throughout the crystallization process may be followed.

The application of these results to refractories and slags of interest in ceramics and metallurgy is briefly discussed.

(1063) Time relations in ocean sediments. C. S. Piggot and Wm. D. Urry. *Bull. Geol. Soc. Amer.*, vol. 53, pp. 1187-1210 (1942).

Nonequilibrium between the radioactive elements in the surface of the ocean bottom provides a method of measuring intervals of time in the past 300,000 years. The well preserved geological and biological history of the ocean basins has been worked out by others for many of the cores of ocean sediments obtained by Piggot, and the above method of measuring time intervals in years has been applied to these cores. The results indicate that the effects of glaciation on the

continents are contemporaneous with equivalent effects on the type of deposit in the ocean bottom; that the effects of glaciation on the type of ocean sediment are widespread, extending in the northern hemisphere at least to the Caribbean Sea; and that within short intervals of time there is in the ocean bottom a considerable variation, attributable directly or indirectly to climatic changes, which, probably because of the continuous effacement of the evidence on land, has not been reported in studies of continental glaciation.

This method cannot compete in accuracy with the use of the annual varved clays for measuring very recent intervals of time, but it has the advantages of (1) application to a considerable area of the earth's surface; (2) reference to the present time; and (3) applicability to at least half of the Pleistocene epoch.

The rate of deposition of ocean sediments is treated as a subsidiary problem. The obvious step from the determination of time intervals in a core to the rate of deposition of the sediment represented by the core is complicated by the present incomplete knowledge of the distortion of the sediment in the process of obtaining the sample. The average rates of deposition agree with estimates by other methods, some of which, however, are open to the same criticism. There is apparently considerable variation in the rate of deposition of ocean sediments in the past, but the data can be only qualitative at present because of the above complication.

- (1064) Pyrrhotite; melting relations and composition. Einar Jensen. *Amer. Jour. Sci.*, vol. 240, pp. 695-709 (1942).

The melting relations of pyrrhotite and adjoining portions of the system FeS-Fe were studied by means of the differential heating-cooling-curve method. The mixtures were sealed in specially designed silica glass containers to prevent oxidation and loss of sulfur at high temperatures. A preparation corresponding to the formula FeS melts over a large temperature interval with dissociation into a solid richer in sulfur and a liquid richer in iron. Increasing sulfur

raises the melting temperatures to a maximum where the composition $\text{Fe}_{12}\text{S}_{13}$ melts sharply like a simple compound. Mixtures with more iron than FeS show eutectic melting. A diagram has been made showing these melting relations, and other relations at lower temperatures taken from the literature.

- (1065) Origin of shapes of quartz sand grains. Earl Ingerson and Joseph L. Ramisch. *Amer. Mineralogist*, vol. 27, pp. 595-606 (1942).

The quartz grains in many metamorphic rocks tend to be elongate parallel to the c-axis. Recently a similar elongation has been observed in the quartz grains of unmetamorphosed sandstones; also another elongation parallel to the unit rhombohedron. Current explanations ascribe these elongations to fractures parallel to these directions and differential abrasion during transport. To check these explanations, three sets of experiments were carried out, with the following results: (1) There was a decided tendency for some samples of quartz to fracture parallel to the unit rhombohedron, but no sample showed a pronounced fracture parallel to the c-axis. (2) Quartz grains from weathered (but undisturbed) quartzose igneous and metamorphic rocks show a tendency to be elongate parallel to prism and unit rhombohedral faces. (3) Abrasion tests on oriented prisms show that quartz is harder on prism faces than normal thereto. It is concluded that the elongation of quartz sand grains is due to original shape rather than to fracture and differential abrasion during transport.

- (1066) A method for the summation of the Fourier series used in the X-ray analysis of crystal structure. A. L. Patterson and George Tunell. *Amer. Mineralogist*, vol. 27, pp. 655-678 (1942).

In recent years there has been a very widespread use of the Fourier series in the analysis of the data obtained by the diffraction of X-rays in crystals. The electron density in a crystal can be represented by a three-dimensional Fourier series in which the coefficients

are the structure factors $F(hkl)$, the intensities of the diffraction lines, corrected for certain known trigonometric factors, being proportional to $|F(hkl)|^2$. The projection of the electron density on a plane perpendicular to a zone axis can be represented by a two-dimensional series using only the F 's of the diffractions in that zone. Various methods leading to the successful analysis of X-ray data have been devised which depend on the summation of Fourier series. Routine methods for carrying out the summation of such series have become part of the necessary equipment of any laboratory specializing in X-ray analysis.

This paper describes in detail a method that has proved useful in the summation of one-dimensional Fourier series, and a procedure that enables this method to be applied to the summation of two-dimensional series such as those by which the electron density of a crystal is represented as a function of the coordinates in the projection of the unit cell on a particular plane. The method, like those of Robertson and of Lipson and Beevers, utilizes cardboard strips, each carrying a series of values of a certain trigonometric function, but differs from the other two in that the selection of numbers to be added from a series of strips for a given point of the unit cell is accomplished by one of a set of stencils, the strips being laid on a rack in the order of the Miller indices of the corresponding crystal planes, and the stencil being laid over the assembly of strips. The stencils are placed over the assembly of strips one at a time in serial order, and the calculated results, in the summation of the two-dimensional series, then give the electron densities along one line of points in the projection. Repetition of this process with the next assembly of strips yields the electron densities along the next line of points. Experience has shown that this method is well adapted to the range of F -values (or of $|F|^2$ -values) from 0 to 1000.

(1067) Apparatus for direct measurement of linear structures. Earl Ingerson. *Amer. Mineralogist*, vol. 27, pp. 721-725 (1942).

Modern methods of metamorphic and igneous geology frequently require that large

numbers of linear elements be measured in the field. Under many circumstances this is a difficult and time-consuming operation with the ordinary compasses in use for geologic surveying.

A piece of apparatus has been devised that can save much time in taking a series of lineation measurements, since only a single placing is required for each measurement. It consists of a compass mounted with a graduated semicircle weighted so that it remains vertical; the compass is provided with a weighted pointer which keeps it horizontal. This arrangement is swung on pivots in a frame having a straight edge that can be placed on, or parallel to, a linear structure in the field. Direction of pitch is read on the compass and angle of pitch is read on the vertical circle.

The apparatus can be used on overhanging surfaces and on outcrops where no planar structure is apparent just as well as on the more commonly encountered type of outcrop. Also, dip and strike can be determined by measuring the dip just as a lineation is measured, and taking the direction normal to the pitch as the strike of the planar structure.

(1068) The binary system CaSiO_3 —diopside and the relations between CaSiO_3 and akermanite. J. F. Schairer and N. L. Bowen. *Amer. Jour. Sci.*, vol. 240, pp. 725-742 (1942).

The system CaSiO_3 —diopside is the type of binary system involving both solid solution and enantiotropism. The temperature of the inversion of wollastonite (βCaSiO_3) to pseudowollastonite (αCaSiO_3) is raised by solid solution of diopside in wollastonite, and in compositions between 0 and 21 per cent diopside there is an inversion interval. In fact, the inversion temperature is raised so much (from 1125° to 1368° C) that wollastonite solid solutions actually appear on the liquidus. There is little or no solid solution of diopside in pseudowollastonite. There is a eutectic at $1358 \pm 2^\circ$ C and at 62 weight per cent diopside. At the eutectic, crystals of pure diopside and of wollastonite solid solution with the maximum amount of diopside (22 per cent) are in equilibrium with

liquid. No CaSiO_3 enters into solid solution in diopside crystals. At temperatures below the eutectic, wollastonite solid solution crystals contain less diopside than at the eutectic, and crystals formed at higher temperatures therefore show the phenomenon of unmixing at lower temperatures.

The system CaSiO_3 —akermanite shows the simple eutectic type of melting diagram with the eutectic between pseudowollastonite and akermanite at $1400 \pm 2^\circ \text{C}$ and at 57 weight per cent akermanite. There is no solid solution of akermanite in either wollastonite or pseudowollastonite. The system is binary at all temperatures at which liquid is present, but because of the instability of akermanite at temperatures below about 1325°C , the system ceases to be binary in certain compositions and at certain temperatures.

The relations between the metasilicate molecules present in pyroxenes and the related pyroxenoids are briefly discussed, and the lack of mutual solid solubility between pyroxenoids and melilites is pointed out.

(1069) The system CaSiO_3 —diopside—anorthite. E. F. Osborn. *Amer. Jour. Sci.*, vol. 240, pp. 751–788 (1942).

The plane CaSiO_3 —diopside—anorthite occupies an important position within that part of the quaternary system CaO — MgO —

Al_2O_3 — SiO_2 of interest to the geologist. New data are presented for compositions lying in this plane, and the phase relations are discussed with the aid of a series of diagrams. A ternary reaction point is present at 1245°C , and the lowest temperature at which liquid exists in the system under equilibrium conditions is 1236° . The alleged compound $5\text{CaO} \cdot 2\text{MgO} \cdot 6\text{SiO}_2$ does not appear in the system, as formerly believed. Data are presented supporting the evidence of Schairer and Bowen that this compound does not exist. The crystals of diopside appearing in the system are slightly aluminous. Consequently, the system is not completely ternary. Some additional data are presented for the limiting systems CaSiO_3 —anorthite and diopside—anorthite.

(1070) Glass. George W. Morey. *In* Rogers' Manual of industrial chemistry, 6th ed., chap. 20, pp. 775–813. New York, D. Van Nostrand Co. (1942). (No separates available for distribution.)

The subjects of this section of the revised edition of the book are treated under the following subheads: historical, definition and structure, composition, properties, manufacture, products, and economics of glasses.

(1071) Annual Report for 1941–1942.

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DEPARTMENT OF TERRESTRIAL MAGNETISM

Washington, District of Columbia

JOHN A. FLEMING, *Director*

SUMMARY

The progress of geophysical research in which international collaboration plays an important part has been further retarded during the report-year, July 1, 1941 to June 30, 1942, by the extension of the war in which all the great powers of the Earth have become involved. Studies of terrestrial magnetism and electricity have not escaped the disastrous effects of this crisis. Field-operations of the Department, which have been one of the international aspects of the regular program, have had to be abandoned until the return of normal intercourse among nations. Fortunately, magnetic surveys by organizations and individuals in many countries have offset in some degree the inadequacy of data caused by this curtailment. Fortunately, also, there are many observatories situated in regions not affected as yet by military operations which are able to continue their recordings and compilations of data on the progress of secular changes, so necessary in keeping isomagnetic charts current for purposes of navigation and surveys in the air and on land and sea.

The widespread demands for application to the war effort of the results of past and present investigations have again emphasized the practical value of the many aspects of the Department's researches in Earth physics. Many of the facilities of personnel, laboratory, shop, and buildings, at Washington and at the observatories, were deflected to investigations and solutions of war problems. A number of the staff were assigned upon request to special duties elsewhere. Thus there has been possible only

a somewhat limited continuation of the regular program; nevertheless, it is possible to include in this report a considerable amount of worth-while development. Many items of scientific value were developed in the investigation of special war problems.

In conformity with the action of the Trustees, the services of the regular scientific and administrative personnel and the use of facilities have been contributed without charge to the government. These services by the 89 budgeted scientific and administrative staff members during the report-year included nearly 36,400 hours and over 6200 hours, respectively, for the two groups; the corresponding totals for the whole period of the emergency since 1940 were 56,400 and 11,200 hours. On June 30, 1942, ten of the regular and temporary personnel were on leave of absence. To assist in the development of urgent projects for the Army and Navy and other governmental agencies, a number of contracts at cost without overhead were undertaken. The peak number of additional investigators engaged on account of these contracts during the year, including physicists, engineers, technicians, and administrative assistants—many through the generous action of universities and industrial organizations in granting leaves of absence for the emergency—was 211.

REVIEW OF YEAR'S PROGRESS

Measures of geomagnetic activity. Reports on the three-hour-range indices of geomagnetic activity were received for the

calendar year 1940 from 25 observatories, that is, 18 in addition to the 5 in the United States of the Coast and Geodetic Survey, and 2 of the Institution in Peru and Western Australia. The disruptions caused by the war have reduced the total number of observatories reporting these indices during 1941 to 19. It is possible, however, to give partial effect to the resolution adopted in 1939 by the International Association of Terrestrial Magnetism and Electricity, according to which the three-hour-range indices were to replace from 1940 the numerical characterization of days previously used. The Department has tabulated, summarized, and published the values supplied.

Geomagnetic investigations. Average values of the disturbance of daily variation, storm-time variation, solar daily variation, daily means of disturbance, and non-cyclic change for international disturbed and quiet days were derived. Tables of post-perturbation and annual variation for the period 1905-1937 were completed. Derivations for the equator were made of the storm-time and disturbance daily variations day by day for the same period. These new data are at present being used in the reduction to epoch of the extensive magnetic measurements by the Department on land and sea. The Department's isoporic charts for the epoch 1920-1925 were redrawn, and results for the region of the Pacific Ocean incorporated therein; use was made of consistency-tests suggested by Chapman in obtaining improved estimates of secular change. An attempt is also being made to obtain, by analytic continuation, improved estimates of measures of the Earth's magnetism in high latitudes from the better-determined values in low and middle latitudes.

The probability of ranges in the magnetic elements greater than various assigned magnitudes was estimated for any

latitude, and the probabilities per day of magnetic storms of various intensities were deduced. A study of methods of prediction of fluctuations in geophysical phenomena from observed changes in the past was continued.

Electric current-systems of bays and the annual variation were deduced. The investigation of the relations of geomagnetic with solar and other cosmic data was continued. Attempts to forecast geomagnetic and ionospheric conditions several days in advance were inaugurated and fair success was attained.

Terrestrial electricity. Ionization-meters were designed, constructed, and tested for use in a more precise investigation of the question whether the amount of radioactive matter in the Earth, measured in recent years by other methods, is adequate to account for the rate at which ions are formed in the air over land by agencies other than cosmic radiation.

Nuclei of condensation, entities which serve as starters in the formation of water-drops and also affect the electrical state of the atmosphere, were further investigated, with special regard to their nature, the sources of supply, the manner of dissemination, and the rate of loss from the atmosphere. The technique of counting these nuclei was also critically studied and decisions were reached on some disputed points.

Investigations of atmospheric-electric phenomena registered at the Institution's observatories (Watheroo in Western Australia and Huancayo in Peru) indicate rather clearly that at Watheroo, during both day and night, nuclei introduced into the atmosphere from sources on the Earth are disseminated throughout a stratum extending from the Earth to a height of at least 1 km; at Huancayo, where nuclei are in much greater concentration than at Watheroo, they are also distributed in a

stratum to a height of about 1.5 km during daytime, but at night in the dry season a shallow stratum of stable air often forms and in this the concentration of nuclei diminishes during the night to less than one-tenth the concentration in daytime. There are corresponding large changes in the atmospheric-electric elements.

Attention was given to a number of practical problems, chiefly in aeronautics, which touch some branch of atmospheric electricity or associated subjects.

Ionosphere. Three complete automatic ionospheric recorders were in continuous operation in the field at the Watheroo, Huancayo, and College observatories. All reductions and tabulations were kept current and promptly forwarded. Extended analyses of the ionospheric data were confined to practical applications of value to the war effort.

Interpretations of ionospheric reactions during magnetic storms were continued. Accumulating evidence indicates a post-perturbation effect which may be worldwide in nature. Following several of the magnetic disturbances, simultaneous rapid decreases of electron-density in the F_2 -region were recorded both at Huancayo and at Watheroo. The trend of recovery and the time of reaching normal conditions at both stations appear to be closely related.

Developmental and experimental work was likewise confined largely to wartime applications. Tests of the automatic camera for the recording of aurora were completed under actual operating conditions at temperatures down to -20° F. The constant-voltage controllers were forwarded to Huancayo and Watheroo following testing and adjustment at the Washington office.

The Department's policy of full cooperation with government agencies and with qualified representatives of allied govern-

ments was continued and expanded. Several papers dealing with ionospheric characteristics and related phenomena including radio wave-propagation were prepared. The technique of measurement of intensity of the Earth's magnetic field in the ionosphere which was applied to observations at Huancayo may introduce an important new field of research linking ionospheric and geomagnetic analyses even more closely than at present.

Nuclear physics. Some progress was made in improved functioning of the pressure electrostatic generator in the Atomic-Physics Observatory, but reasonable expectations of 4 to 5 million electron-volts on the tube for this generator are not yet attained.

Although slowed down by lack of personnel and difficulties in obtaining materials and appurtenances, the 60-inch cyclotron installation was so well advanced that satisfactory tests of magnet and vacuum-system (including pumps, valves, vacuum-chamber, and radio-frequency electrode housing) could be made. The vacuum-pressure was lower than 5×10^{-6} mm of mercury. The magnet was found to produce a field greater than 17,000 gauss. In terms of probable deuteron-beam energy, this field promises an upper limit of about 27 million electron-volts—considerably more than there was reason to expect from experience elsewhere.

The advantages of the use of this equipment for producing artificially radioactivated materials for investigations in chemistry, biology, and physics are obvious. The cooperation of the National Cancer Institute was most helpful, especially so as that organization continued the assignment of Physicist D. B. Cowie, of its staff, to this project; in the absence of the regular staff of physicists of the Department, he and the technicians working with him are

to be credited with a large measure of the progress made.

Observatory- and field-work. In collaboration with the University of Alaska, the Observatory at College was maintained and magnetic and auroral programs were initiated early in the report-year. The Huancayo and Watheroo magnetic observatories continued extensive geophysical observations as heretofore. Cooperation at Apia in atmospheric electricity was concluded December 31, 1941. The recordings of the atmospheric-electric elements and earth-currents in cooperation with the United States Coast and Geodetic Survey and Bell Laboratories at the Tucson Observatory were continued, as was the maintenance of international magnetic standards at the Cheltenham Magnetic Observatory of the United States Coast and Geodetic Survey. Constant contact with the Division of Geomagnetism and Seismology of the Survey has been mutually advantageous, the more so now that the Survey is undertaking extensive reoccupations of CIW and other stations in South and Central America.

To complete the geomagnetic and auroral compilations and discussions of the United States Antarctic Expedition of 1940-1941, the facilities of the Department were extended, at the request of the United States Department of the Interior, for the whole year to R. G. Fitzsimmons and for five months to M. A. Wiener, of that Expedition.

Cooperative work was continued with surveys in Africa, Australia, and New Zealand and at observatories in South Africa, Samoa, Greenland, and Mauritius through the loan of CIW instruments, supplying of materials, and preparation of instructions.

Miscellaneous. Two of the retired members of the staff, who had contributed largely to the operations of the Department, have died. Carroll Christopher Ennis died November 24, 1941, after an enviable record of service to geomagnetism and oceanography. William John Peters, who was largely responsible for the successful development of the Institution's extensive surveys at sea on the *Galilee* and the *Carnegie* and for many geomagnetic investigations, died July 10, 1942, just after the close of the report-year. Both these men were unique in their scholarly qualifications and devoted unselfish service to science.

The Department was fortunate in having on active duty three others of its retired staff—J. W. Green, A. Smith, and W. F. Wallis—who did much to carry on as replacements for younger men assigned to war problems.

Although the bibliography accompanying this report shows fewer publications than during the preceding year, it gives ample evidence of the wide range of the activities of the staff.

INVESTIGATIONAL AND EXPERIMENTAL WORK

TERRESTRIAL MAGNETISM

Those of the staff chiefly engaged at Washington on investigational and experimental work relating particularly to geomagnetism were Fleming, J. W. Green, Johnston, Miss Lange, McNish, Scott, Torreson, Vestine, Wallis, and Wells. Chap-

man at London gave constructive advice and made theoretical investigations which have proved of great value to the Department's program. A considerable portion of the time of each, in some cases almost all, was given to work on special analyses and

compilations and on instruments concerned with the war effort. The following statements regarding the several items of investigation summarize only a part of the work actually done.

PERMANENT FIELD

Analysis of geomagnetic field. The investigation of methods of field-analysis and use of computing-machines to facilitate such analysis were continued by Vestine. To conclude the project of field-analyses by integrals on the theoretical side, an attempt was made to obtain a more compact expression for a function giving external current-systems corresponding to any observed magnetic field at the Earth's surface. Two methods previously worked out give a complete and exact solution but are rather slow in application. This function is intimately associated with the height of electric current-systems above the Earth compatible with observed surface fields.

A study was made of the world-wide distribution of magnetic anomalies. Large anomalies appear in volcanic regions, where rocks such as granite and basalt, magnetized on cooling below the Curie-point, are likely to be common, and consequently also in earthquake-zones. A collection was also made of material and charts showing locations of ferromagnetic mineral deposits, where magnetic anomalies may be expected.

Reduction of field-data to mean epochs. The construction of new world isoporic charts for the epoch 1930-1935 was continued and preliminary steps were taken to construct similar charts for the epoch 1940-1945. Geomagnetic charts of the present epoch show large systematic errors, and the new isoporic charts should assist materially in providing the more accurate rates of secular change needed for their improvement and the best use of the avail-

able material. The isoporic charts developed at the Department by Fisk for the epoch 1920-1925 were replotted on Mercator's projection and tested for mutual consistency in the case of the isopors for horizontal intensity and declination. For declination, this method is being used in obtaining a compromise between the results of Fisk and Duvall for the region of the Pacific Ocean. The estimates based on Chapman's modification of Schuster's curl-method (see p. 44) show marked evidence of inconsistencies, and the problem of adjustment of the isopors so that the results for horizontal intensity and declination will be mutually consistent is being studied.

Tables to correct field-observations for post-perturbation and annual variation were prepared for all days of the period 1905-1937. Since disturbances vary both in number and in intensity with time of year, they contribute the major part of an apparent annual variation. This variation throughout low and middle latitudes is most marked in the geomagnetic north component, for which it has an amplitude of the order of about 10 gammas ($1\gamma = 0.00001$ CGS unit).

The annual variation was derived using data for about 65 observatories of the Polar Year, 1932-1933. The results proved satisfactory for the geomagnetic north and east components, but were highly erratic for the vertical component except in high latitudes. A similar derivation was made for a period of 24 years for 10 stations in low and middle latitudes; the results for the vertical component were again found to be somewhat erratic. The geomagnetic north component is small near the geomagnetic poles and increases rapidly equatorward to a maximum at the auroral zone. Just outside the auroral zone this component diminishes rapidly with decreasing

latitude and attains a secondary maximum near the equator. The geomagnetic east component was found to be small in all latitudes. The vertical component is largest near the center of the auroral zone and zero near the equator, where a reversal in sign occurs.

The annual variation can be separated into two parts. One part is symmetrical about the equator with a minimum near the equinoxes, and varies with latitude in proportion to the annual average of disturbance in amplitude. Cynk showed that the remaining part is nearly sinusoidal in character with a period of one year, with minimum at the winter solstice and maximum at the summer solstice. The annual variation thus comprises both an annual and a seasonal component.

The annual variation varies in amplitude with sunspot-cycle, the amplitude for years of sunspot-maximum being about twice that for years of sunspot-minimum.

A possible electric current-system of the part symmetrical about the equator closely resembles that corresponding to the annual average of the daily means of disturbance, if the lines of current-flow are assumed to flow in closed circuits in a thin layer in the Earth's atmosphere at constant height. Lines of current flow from east to west in all latitudes, with maximum concentration of current in polar regions. In the case of the sinusoidal part, the current-lines are roughly along parallels of geomagnetic latitude opposite in direction in the Northern and Southern hemispheres, and increase in intensity from zero near the equator to a maximum in polar regions, where the variation with time of year is marked. This notable seasonal variation also gives rise to considerable distortion in the average current-system of geomagnetic disturbance.

The development of methods for the reduction of field-observations to mean of

day on a world-wide scale was continued. For this purpose the solar daily variation (S_q), disturbance daily variation (S_D), storm-time variation (D_{st}), and irregular disturbances (D_i) are being derived for individual days. Using estimates based on graphs for two and three stations spaced roughly 120° and 180° apart in longitude in equatorial regions, the means according to hour of Greenwich time appear to give a rather good estimate of the storm-time variation. The estimated corrections in the case of S_D are less satisfactorily determined. In the case of S_q use is being made of average values corrected in amplitude for sunspot-variation, and for daily variability by inspection of magnetograms at one station.

Mathematical treatment of geomagnetic charts. Chapman continued his discussions of isomagnetic charts, embodying his results in three additional papers. They dealt with the following subjects: "Earth-air electric currents and the mutual consistency of H and D isomagnetic charts"; "Mathematical notes on isoporic charts and their singular points"; "The mutual consistency of the declination and horizontal-intensity isoporic charts." These discussions and the methods proposed have already proved most useful in the revision of isomagnetic and isoporic charts with that greater accuracy required for more recent epochs and for use in analyzing the permanent field.

MAGNETIC DISTURBANCES AND COSMIC RELATIONS

A study was made of the frequency and current-systems of geomagnetic bays, using extensive data of the Second International Polar Year, 1932-1933. The daily and annual frequencies of bays were examined for groups of stations in four different latitude-zones: (I) near the geomagnetic north

pole; (II) the auroral zone; (III) middle latitudes; and (IV) the equator. The new results show that bays appear with about equal average frequency at all times of day, the apparent marked variations in frequency with local geomagnetic time found in zones II to IV being occasioned by a notable variation in the amplitude of bays with time of day. In all latitudes bays appear with an average amplitude greater at the equinoxes than at the solstices.

Heights of the polar part of the electric current-system of bays were estimated in two different ways, for two simple assumed forms or models. The heights obtained agreed well with previous, though less detailed, results of Birkeland, Goldie, Vestine and Chapman, and McNish, and place the probable location near the *E*-region of the ionosphere.

An approximation to the average current-system of bays was deduced, assuming the currents to be confined to a spherical shell concentric with the Earth, at a height of 150 km, and using averaged vector-changes of many bays taken for time of maximum. This current-system differs from that proposed for magnetic storms by Chapman, and subsequently considered by Goldie and Vestine, in that there appears little evidence of a storm-time part (D_{st}); the current-system resembles that for the diurnally varying component (S_D) of storms, though notably distorted in polar regions. In these regions important seasonal changes in the current-distribution were also found in individual bays. This simple current-system was found to afford a fairly satisfactory possible explanation, both qualitative and quantitative, of the world-wide incidence of bays in frequency and amplitude.

Investigations by Wells of relations between the four major magnetic disturbances of 1941 and 1942 (March 1, July 4-5, and September 18, 1941, and March 1,

1942) and ionospheric changes are summarized on pages 56-57. Data for the great magnetic storms of the present sun-spot-cycle were tabulated and discussed by McNish.

In cooperation with five astronomical observatories (Navy, Mount Wilson, McMath-Hulbert, Climax of Harvard University, and Whitin of Wellesley College) and with geophysical observatories of the Institution and others in Australia, Canada, and New Zealand, more intensive research on the correlation of solar, ionospheric, and geomagnetic disturbances was begun. There has already been developed a means of forecasting, with fair success, ionospheric and magnetic disturbances for four to five days in advance. The results of these investigations are being closely coordinated with the effects on radio conditions, in cooperation with the National Bureau of Standards.

The experimental investigation of the upper atmosphere using modulated searchlight beams, reported upon last year (Year Book No. 40, pp. 66-68), had to be deferred because all the personnel engaged on it were on leave of absence in connection with war efforts. Meanwhile the searchlights and associated equipment have been properly housed at the Kensington and Washington stations.

Cosmic-ray investigations. On behalf of the Institution's Committee on Coordination of Cosmic-Ray Investigations, the necessary attention (Lange, Forbush, and Fleming) was given to the maintenance of CIW precision cosmic-ray meters at five observatories. Because of leave of absence for war work, Forbush could devote only a small amount of time to the compilation and discussion of records obtained; greater responsibility had therefore to be taken by Miss Lange in these matters. A notable disturbance was that coincident with the magnetic storm of March

1, 1942, which was reported upon by Miss Lange and Forbush, V. F. Hess, and others. The report of the Committee (Year Book No. 41, pp. 87-102) briefly abstracts the results of this study and others.

ARCHIVES OF MAGNETIC RECORDS

The microfilm copies of records acquired during the Second International Polar Year, 1932-1933, have again proved of great value, especially in the improvement of isomagnetic charts required for military use.

Ennis began a complete revision of annual values of the geomagnetic elements as given in publications and reports of the world's observatories. Following his death, this compilation was completed by Scott. The lists show the observed and computed annual values at over 100 principal existing and discontinued observatories for declination, inclination, and horizontal, north-south, east-west, vertical, and total components of the Earth's field. These values will supply investigators with the published magnetic results as well as with computed values of such of the elements as are not included in the publications. In the case of some of the observatories—fortunately not many—there was evidence of a lack of accuracy in the computational or observational work; every effort was made to correct such errors of computation and to check the derivation of those of the seven elements and components which must depend upon the three elements usually recorded, that is, declination, horizontal intensity, and inclination,

or declination, horizontal intensity, and vertical intensity.

INSTRUMENTAL DEVELOPMENTS

Electromagnetic standard. Analysis of the absolute measurements, completely checked by Wallis and Scott this year, on the electromagnetic standard (see Year Book No. 40, p. 68) shows that the diameter of the coil is known to $\frac{1}{2}$ part in a million (0.5×10^{-6}) and that the coil-lengths are correct to $1\frac{1}{2}$ parts in a million (1.5×10^{-6}). The pitch of the coils varies less than ± 2 microns. The temperature-coefficient was determined to be approximately 5 parts in a million (5×10^{-6}) per degree centigrade. On the basis of these measurements, the absolute value of the vertical component of the Earth's magnetic field at the Cheltenham Magnetic Observatory, where the instrument, when completed, is to be installed as the standard of intensity, will be known to 0.5 gamma and the horizontal component to 0.3 gamma. The assembly of the instrument must of necessity be deferred until personnel and shop facilities can be released from their present war duties.

New magnetometer design. The development of new and simple instruments for field-observations reported last year (see Year Book No. 40, p. 68) is being actively continued.

Automatic auroral camera. As reported on page 77 of this report, the automatic auroral camera was completed and is functioning quite satisfactorily at the College Observatory in Alaska.

TERRESTRIAL ELECTRICITY

Research in terrestrial electricity was considerably reduced because of demands made upon the staff by the war effort. In geoelectricity, the data obtained at the ob-

servatories were examined only to the extent required to ascertain that a high standard of reliability is being maintained; in atmospheric electricity, aside from routine

checks and the reduction of data, some investigations were made by Gish, Sherman, and Wait, and the investigation of condensation-nuclei was continued throughout the report-year by Research Assistant Marcella Lindeman Phillips. Rooney and Torreson were engaged throughout the year on war projects, and all other members of the section devoted varying proportions of their effort to such matters. Some results from this endeavor, in addition to their primary bearing on practical affairs, have interest for geophysics.

ATMOSPHERIC ELECTRICITY

Electrical state of the atmosphere. An electrical charge in a portion of the atmosphere or the charge on a raindrop is dispersed or lost at a rate depending on the amount of charge and the electrical conductivity of air. The electrical state of the atmosphere is also related in other ways to the electrical conductivity of the air, which in turn depends on the presence of ions, small electrically charged "particles." When the latter are driven by electrical or other forces they effect a transport of electricity. The rate of transportation is proportional to the number of carriers, or ions, their velocity, and the load (electrical charge) borne by each carrier. The load is apparently the same for practically all the carriers, namely, one elementary unit of electric charge. The velocity, however, varies widely. It depends of course on the driving force (electric field-strength or potential-gradient), but also on the nature of the ions, chiefly their size. The "small ions" in the air near the Earth have a size equivalent to that of a few molecules, and attain velocities between 1 and 2 cm per second when in an electric field of 1 volt per cm, but with the same driving force the "large ions," equivalent in size to about a million simple molecules, attain a ve-

locity of only a few ten-thousandths cm per second. Since each of these large ions usually carries the same amount of charge as a small ion, the large ions can contribute comparatively little to the transport of electricity through the air unless their number is very great as compared with that of the small ions. Though usually negligible in this respect, the large ions, or rather the entities (nuclei of condensation) from which they are formed, play an important role in atmospheric electricity because they are usually formed from the nuclei of condensation at the expense of small ions. Thus an increase in the concentration of large ions entails a decrease in the concentration of small ions and a nearly corresponding decrease in the electrical conductivity of air.

The conductivity of the atmosphere also depends on the rate at which small ions are formed. The principal recognized ion-forming agents in the air near the Earth are the cosmic radiation and radiations from radioactive matter in the Earth and in the atmosphere.

The foregoing considerations suggested investigations of the following subjects: (a) the nuclei of condensation; (b) the sources from which these nuclei come; (c) how they are disseminated in the atmosphere; (d) how they are finally lost; and (e) the rate of formation of small ions in the atmosphere by radiations from radioactive matter in the Earth. Other investigations included analyses and interpretations of various aspects of the registrations, obtained at the Institution's magnetic observatories, of the several atmospheric-electric elements.

Rate of ion-formation. Because of the following observed facts, it has been questioned whether the rate of ion-formation by known ionizing agents is adequate to account for the number of small ions in the lower atmosphere. (a) The rate of

ion-formation inside chambers with thick walls (3-mm brass) is several times greater than that to be expected on the basis of the values reported by Evans and Goodman for the radioactive material in rocks. (b) The variation of this rate with time, in either thin- or thick-walled chambers, shows differences with respect to character and amplitude which would hardly be inferred from available information regarding the kind and quantity of radioactive matter in the Earth (Gish). General plans for the solution of the problem which results from (a) were described by Hess (*Terrestrial Magnetism*, vol. 46, pp. 409-415, 1941). The apparatus designed by Gish for use with a null method was constructed in the instrument-shop of the Department, precise determinations of the constants were made by Sherman, and a preliminary investigation of the general performance of the equipment was made by Gish and Sherman. The chief results of the latter are: (a) Contact-potentials are entirely negligible; (b) the rate of ionization from a known amount of radium is in satisfactory agreement with values found by others with comparable equipment; (c) in a laboratory room a rate of ionization of 6.8 ion-pairs per cubic centimeter per second was found; (d) there appears to be no appreciable amount of radioactive matter in the material (brass) from which the ionization-chambers are made—a favorable but unexpected circumstance; (e) ionization by secondary radiation, of low penetrating power, excited in the walls of the chamber by gamma radiation is apparently revealed by this method of investigation when the chambers are exposed to the radiations from a specimen of radium, but no such effect is definitely indicated by exposure to the radiation from the radioactive matter normally present in the walls, etc., of the room. Further investigation is re-

quired to ascertain the extent to which this result must be taken into account in the final interpretation. These ionization-meters are to be used by Hess and associates at Fordham University to ascertain whether the low values recently reported for the radioactive content of rocks and other earth-materials can be verified by this method.

Sources of condensation-nuclei. Many nuclei are supplied to the air by boiling water; their number increases rapidly from the time when bubbles begin to rise (Gish, Sherman, Phillips). The steam-plume from a tea-kettle contains many more water-droplets than the number of nuclei normally present in air. This increase is probably due partly to the breaking of water-films—nuclei are formed when water and other liquids are atomized.

Nuclei are produced in abundance when drops of water fall upon a hot metal surface. Metal while being heated below incandescence gives off nuclei for a few minutes, provided this property has not been destroyed by heating some days previously.

Nuclei, at least such as can be detected with an Aitken nuclei-counter, are not given off from the undisturbed surface of most liquids at normal temperature and pressure. When these liquids are atomized, however, an appreciable number of nuclei are produced. Nuclei may be formed from the molecules of various vapors by sufficient sudden cooling. When the latter occurs, the concentration is sometimes so great, and consequently the size of the drops formed in the counter so small, that nuclei thus produced may escape detection. Earlier observations (Wait) indicated that nuclei are numerous in exhaled air, but current observations (Phillips) failed to confirm this. No explanation for these divergent results was found.

Dissemination of condensation-nuclei.

The dissemination of condensation-nuclei in the air obviously depends chiefly on the motion and mixing of the air. Specific information about the rate and manner of dissemination in a closed room was required for an investigation of the rate at which nuclei are lost from the air. The rate of dissemination was found (Phillips) to be such that in the quiescent air of a closed bedroom the nuclei became uniformly distributed from floor to ceiling in about one-half hour after introduction from an atomizer or other source; no evidence was found of a distribution of nuclei in strata such as has been reported by Landsberg.

The rate of loss of nuclei from the air or the rate of decrease in the number of nuclei in the air may be attributed to either or both of the following processes: (a) Nuclei may coalesce and form larger entities which settle out of the air; (b) they may reach the Earth's surface or the walls of rooms, etc., simply by diffusion, and adhere to the surface of these. The rate of diminution in the concentration of nuclei should be proportional to the square of the concentration in the first case and simply proportional to the concentration in the second case. If both these processes are active, the diminution may at the start, when the concentration is large, vary more nearly as the square, and later as the first power of the concentration. This tendency was evident in a fair proportion of the series of observations (Phillips) made in closed rooms, and in chambers of much smaller volume, using nuclei from different sources. The diminution, however, was found to depend to some extent on the nature of the nuclei, that is, on the source of supply. The diminution-rate is greater for nuclei formed from the more volatile liquids, and those produced by "condensation upon molecules" appear to be less stable than others.

Method of counting nuclei. The method of counting nuclei received some further attention (Gish, Phillips). The claim has been made that the small ions in the air are "counted" in the Aitken pocket nuclei-counter. Further evidence against this claim was obtained in an experiment designed for another purpose, namely, to ascertain whether in the air there are nuclei of different classes with respect to their effectiveness in condensation. In order to form a droplet about a nucleus, the air in the counting chamber (saturated with water-vapor) is suddenly expanded and consequently cooled. Less expansion (a smaller ratio of expanded volume to initial volume) should be required for nuclei which have a greater than for those which have a smaller affinity for water. Within the range of expansions (expansion-ratios 1.05 to 1.35) obtainable without modifying the counter, the total number of droplets which could be precipitated from a sample of room air containing nuclei did not vary significantly; that is, all entities which serve as nuclei of condensation in this counter can be precipitated by very little expansion, or very little supersaturation, of the air. It is therefore concluded that all these entities are about equally effective as condensation-nuclei and that small ions are not counted. All nuclei are not precipitated, however, by the first expansion of a sample; about 60 per cent of those present just before an expansion are precipitated when an expansion-ratio of 1.30 is used, and about 40 per cent for an expansion-ratio of 1.05 (at average room temperature). But if the sample is expanded repeatedly until no more droplets are formed, the total number of droplets obtained from comparable samples apparently does not depend on the expansion-ratio. This finding supports the view that repeated expansions are required in order to remove all nuclei and that the sum of

the droplets counted in these expansions is the best measure of the concentration of nuclei. In the normal practice with this type of counter, when the largest expansion-ratio (1.35) is used, five successive expansions are required to precipitate 99 per cent of the nuclei; but for the smallest expansion-ratio used in these experiments (1.06), ten expansions are required to precipitate the same proportion of the nuclei. Obviously the tedium of counting is reduced by using the larger expansion-ratio. Little further improvement in this direction could be realized, however, by providing the counter with a longer pump, thus making larger expansion-ratios available, because the stage where condensation on small ions sets in is apparently reached when expansion-ratios slightly greater than that now available are used.

Modifications in atmospheric-electric elements caused by condensation-nuclei. Condensation-nuclei in the atmosphere at the Huancayo Magnetic Observatory effect extraordinary modifications in the atmospheric-electric phenomena observed there. This was first inferred from a study (Gish, Year Book No. 37, p. 15) of the registrations made at that Observatory of the atmospheric-electric and meteorological elements. The three important modifications of the electrical phenomena are: (a) The measured electric current, which flows from air to Earth, is certainly less than one-half that which would be expected at such a high altitude (11,000 feet). (b) The contribution by negative ions to the electric conductivity of air at night is often greater than that by positive ions at this place, whereas the contribution by positive ions usually is the greater at other places. (c) The diurnal variation of potential-gradient and of air-conductivity is remarkable for the large and abrupt change (four- to five-fold) which occurs between 06^h and 08^h almost daily during the dry season.

A tentative explanation of these features proposed by Gish is briefly as follows: Regular observations (counts) of nuclei at 08^h each day had shown that the nuclei-concentration is much greater than is to be expected, considering the immediate environment of the Observatory. Hence the nuclei are thought to come from a distant source and to be carried by the more general air-circulation. They are introduced into the air near the surface at the Observatory by turbulent stirring (eddy-diffusion) when that process is active. When the lower air becomes stable, however, which is most likely at night, turbulent mixing of this with the higher stratum becomes less effective, and the rate at which nuclei are supplied to the lower air is reduced. Then the nuclei-concentration near the surface decreases and the air-conductivity increases. In the morning after sunrise, when the air in the lowest stratum becomes sufficiently heated, mixing of the lower with the higher overrunning air sets in and nuclei are again supplied to the surface-air from above. The ensuing increase in nuclei-concentration entails a decrease in air-conductivity. If the stable lower stratum which develops at night is shallow (say 100 meters), and the nuclei-concentration in the general circulation does not vary from night to day, the electrical resistance of a vertical air-column from the Earth to a height of some tens of kilometers is modified very little by the change in conductivity from night to day. Hence only a very small corresponding change in air-earth current is to be expected and the potential-gradient should vary inversely as the conductivity. The recorded data are in accord with these expectations.

The relation between values of negative and positive conductivity observed at night (the former exceeding the latter) is a simple consequence of the decrease of total

conductivity with altitude in the air near the Earth's surface. This observation also indicates that the lower stratum extends to a comparatively small height. Rough estimates, by two independent methods, had indicated that it is probably not less than 10 meters nor more than 100 meters.

The height to which the variation of conductivity at the surface extends was estimated (Wait) during the present year by a more extensive examination of the electric data. Not only was the low value previously estimated for the height of the lowest nighttime stratum verified by this examination, but it was also found that the average diurnal changes in air-conductivity at this place are confined to a shallow stratum.

On 15 days in August 1941 special observations of the nuclei-concentration were made (Jones, Ledig) at the Huancayo Magnetic Observatory at 06^h and 07^h in addition to the regular observations at 08^h, in order to ascertain whether nuclei are as scarce at night as is implied by the proposed explanation outlined above. These observations show a contrast in nuclei-concentration considerably greater than that in conductivity. The average count of nuclei at 08^h was 10.9 times that at 06^h, whereas the average conductivity at 06^h was 3.6 times that at 08^h. The proportional change in concentration of nuclei is larger, as compared with that in conductivity, than is usually found at other places, but studies of the regular nuclei-counts at 08^h at Huancayo (Gish, Torreson, Year Book No. 38, pp. 74-75) revealed a comparable tendency in the variations from day to day. Such a tendency may arise in several ways. The one which now seems most plausible (Gish) is that the nuclei in the lower air at night are of different character from those present in daytime. The former, perhaps chiefly of local origin, "combine" more readily with the small

ions in the air than do the latter, which doubtless come from a very different distant source. The rate of combination between the small ions and the nuclei from the distant source appears to be notably smaller than in any other case thus far reported. In brief, these early-morning observations of nuclei have not only corroborated the proposed explanation for three outstanding aspects of atmospheric electricity at Huancayo, but have also shed light upon some other matters, for example the rate of combination between nuclei and small ions.

Condensation-nuclei in the atmosphere at the Watheroo Magnetic Observatory modify the atmospheric-electric elements in a manner different from that at Huancayo, but no less interesting. This fact was brought out more clearly than heretofore by analyses made by Wait.

The method of analysis is based upon the fact that nuclei and some other agents generally affect the electric state of the atmosphere to a much greater degree over land than over sea. Accordingly the atmospheric-electric data obtained on cruises of the *Carnegie* have frequently been used as a standard for comparison with other data. These studies have indicated the desirability of making a more precise comparison using data observed simultaneously on land and at sea.

Material for such a comparison was obtained at the Watheroo Magnetic Observatory and on board the *Carnegie* during 1928-1929. Thus far the data for 42 fair-weather days in November-December 1928 and January-February 1929 have been compared (Wait). Of these 42 days, 17 are classed as "smoky" and 25 as "non-smoky" at Watheroo. The concentration of nuclei is of course much greater on days in the first than on days in the second category, hence the terms "smoky" and "non-smoky" connote a relatively large

and a relatively small concentration of nuclei, respectively.

The essential features of the data for potential-gradient and for air-earth current are conveniently expressed by the Fourier series, $y = \bar{y} + \sum(a_n \cos n\theta + b_n \sin n\theta)$, where θ in degrees is 15 times the time in hours counted from Greenwich midnight. The coefficients of the first four harmonics are listed in table 1.

the latter method, but the diurnal variation of these values obtained by the former was of about the same character as that for values obtained by the latter method. The average was 4 per cent lower for non-smoky and 14 per cent lower for smoky days; ranges 0 to 9 and 8 to 25 per cent, respectively.

An inspection of table 1 discloses that, although the mean potential-gradient at

TABLE 1

COMPARISON OF FOURIER COEFFICIENTS FOR POTENTIAL-GRADIENT (X) IN VOLTS PER METER AND AIR-EARTH CURRENT (i) IN 10^{-7} ESU AT SEA AND AT WATHEROO MAGNETIC OBSERVATORY

CONDITION AT WATHEROO	ELE- MENT	MEAN	FOURIER COEFFICIENTS								GMT MAXI- MUM (h)	RATIO* (<i>c</i> ₂ / <i>c</i> ₁)
			24-hr.		12-hr.		8-hr.		6-hr.			
			<i>a</i> ₁	<i>b</i> ₁	<i>a</i> ₂	<i>b</i> ₂	<i>a</i> ₃	<i>b</i> ₃	<i>a</i> ₄	<i>b</i> ₄		
AT SEA, <i>Carnegie</i>												
Smoky	<i>X</i> . .	146	− 8.9	−22.5	−5.2	−0.9	−1.2	−1.6	+1.7	+1.9	16.6	0.22
	<i>i</i> . . .	9.7	− 0.48	− 1.62	−0.44	−0.10	−0.04	−0.05	+0.16	+0.04	16.8	0.26
Non-smoky . .	<i>X</i> . .	130	− 7.7	−22.9	−7.0	−1.8	−0.4	−2.0	0.0	+1.2	16.8	0.30
	<i>i</i> . . .	8.8	− 0.51	− 1.57	−0.46	−0.14	−0.01	−0.14	−0.01	+0.06	16.9	0.29
ON LAND, WATHEROO MAGNETIC OBSERVATORY												
Smoky	<i>X</i> . .	123	− 8.7	−33.8	−6.7	−7.2	−5.4	−3.8	+1.9	+1.9	17.0	0.28
	<i>i</i> . . .	9.1	+ 0.33	− 0.29	+0.02	+0.16	+0.05	−0.37	0.00	+0.08	21.3	0.37
Non-smoky . .	<i>X</i> . .	89	−13.6	−14.9	−2.3	+1.4	+1.6	−2.9	+1.2	−0.6	15.2	0.13
	<i>i</i> . . .	8.6	− 0.14	− 1.07	−0.20	+0.20	+0.11	−0.12	−0.03	0.00	17.5	0.26

* Ratio of amplitudes (c_2/c_1) = $(\sqrt{a_2^2 + b_2^2} / \sqrt{a_1^2 + b_1^2})$.

The values used for air-earth current in this analysis are the products of corresponding individual values of potential-gradient and of total air-conductivity, not the products of corresponding mean values. The importance of calculating values of air-earth current in this way was again emphasized (Year Book No. 40, p. 76) by a comparison of the values calculated both ways with data for 108 days at Watheroo. Nearly all values calculated by the former, more exact but more tedious, method were lower than those obtained by

sea was significantly greater than at Watheroo on both classes of days, the mean air-earth current-density was nearly the same at the two places. On smoky days the character of the diurnal variation of current differs between land and sea more than that for other corresponding elements—the maximum for the 24-hour harmonic occurs 4.5 hours later on land than at sea and this component is less prominent. Some of the other differences, however, are also significant. These differences are revealed more clearly, and in a form more

susceptible of interpretation, by an examination of the diurnal variation in the ratio of air-earth current at sea to air-earth current on land for corresponding hours.

The electrical resistance of a vertical column of air of 1 cm^2 cross-section, extending upward from the Earth to the level of great conductivity (some tens of kilometers), is directly proportional to the ratio of air-earth current at sea to that on land. This "columnar resistance" has a definite daily period, being smaller in daytime than at night and essentially of the same character as that determined previously from nonsimultaneous data on land and at sea (Year Book No. 40, p. 77).

The average columnar resistance on smoky days is greater than that on non-smoky days, but the minima are nearly equal; thus the difference on the two types of day occurs chiefly at night. The data for the nine Februaries from 1926 to 1934 show an average resistance 20 per cent greater for smoky than for non-smoky days: the minimum excess on smoky days was 11 per cent and the maximum 30 per cent.

An explanation (Wait) of the variation in columnar resistance at Watheroo on smoky days is that smoke, and the associated condensation-nuclei, are introduced into the atmosphere principally at night and dispersed to a height sufficient to increase the columnar resistance and reduce the air-earth current, as observed. Smoke occurs almost exclusively in the summer months (November to February) and at night. This agrees with the observed responses in the registrations of potential-gradient and air-conductivity. Days in summer on which smoke is observed do not differ appreciably from those without noticeable smoke in respect to wind-velocity, wind-direction, or air-temperature. Disturbances caused by smoke hamper investigations of the more general

aspects of atmospheric electricity, but reveal several features of geophysical interest.

The height to which smoke of local origin rises at Watheroo on the average summer day can be estimated roughly from the change in columnar resistance, assuming that the air-conductivity as affected by smoke is uniform from the Earth's surface up to a definite height. The height thus estimated (Wait) from simultaneous observations on land and at sea for smoky days is 1.5 km, and the height estimated from the much more extensive data for Februaries of 1926-1934 is 1.0 km. For non-smoky days the estimated effective height of the nuclei-bearing layer is 1.6 km for both groups, and there is no evidence of appreciable changes during the day. By the method used in estimating the effective height of the nuclei-bearing lower stratum, estimates are also obtained for the part contributed to the columnar resistance by atmosphere above that height. The point of interest in the latter is that that portion of the columnar resistance is apparently the same on smoky as on non-smoky days and is also essentially the same as that for the corresponding region of the atmosphere derived by Gish and Sherman from air-conductivity data registered on the stratosphere flight in November 1935. This indicates that the air above the estimated effective height is not usually contaminated by nuclei coming from the Earth. The conclusions are: (a) that, on the average, at Watheroo nuclei arising from the Earth are distributed throughout a layer of air extending from the Earth upward to an effective height of at least 1 km, and generally not beyond this; (b) that this height does not vary much during the day; and (c) that it is about the same on smoky as on non-smoky days. The last conclusion is consistent with the observation, already men-

tioned, that smoky and non-smoky days, on the average, have the same meteorological characteristics.

The question of dissemination of nuclei by wind at Watheroo is apparently clarified by results obtained from a statistical examination (Wait) of potential-gradient and wind-velocity data for the months of January, February, and March 1926-1934: (a) On non-smoky days the average potential-gradient increases from 87 volts per meter for zero wind-velocity to 105 volts per meter for a wind-velocity of 5 miles per hour, and for higher velocities there is little further change in potential-gradient; (b) on smoky days the average potential-gradient increases from 217 volts per meter for zero velocity to a maximum of 225 volts per meter for a velocity of 2 miles per hour, and then gradually diminishes to about 180 volts per meter for a velocity of 12 miles per hour. The concentration of nuclei doubtless varies in a similar manner. The interpretations are: (a) that on days of both classes nuclei are brought into the more immediate vicinity of the Observatory by wind, but in greater concentration on smoky days than on non-smoky days; (b) that the source of the nuclei on non-

smoky days is probably more distant and spread over a wider area than that for smoky days; (c) that the source of the nuclei for smoky days is confined to a limited area which is probably not many miles from the Observatory. The last is consistent with the observation that most of the smoke noticed at Watheroo comes from bush-fires. Some wind is required to bring smoke to the Observatory, but since wind-turbulence increases with wind-velocity, the smoke is dispersed more rapidly at the higher wind-velocities. Under the joint action of these two factors the density of smoke (or concentration of nuclei) at the Observatory may be expected to increase with wind-velocity for low velocities, reach a maximum, and then decrease with further increase of velocity.

Cooperation and consultation. On the occasions of several visits at the Department and through correspondence, members of the staff profited from stimulating discussions of current problems with Professor Victor F. Hess, of Fordham University. Gish served on the Subcommittee on Lightning Hazards to Aircraft of the National Advisory Committee for Aeronautics.

INVESTIGATIONS OF THE IONOSPHERE AND ITS RELATION TO PROBLEMS OF GEOMAGNETISM

The external part of the Earth's magnetic field arises from electric current-systems which probably circulate in the ionosphere. Detailed and accurate knowledge of ionospheric characteristics therefore provides a basis for extending and evaluating analyses of the external part of the Earth's magnetic field.

Early theoretical work by Gauss, which was later extended by Stewart and Schuster, required current-systems in the Earth's outer atmosphere to explain certain observed variations in geomagnetism. It was

argued that such current-systems could arise in highly ionized regions far above the Earth. Years later, when Marconi performed his famous demonstration of long-distance radio communication between England and Newfoundland, Kennelly and Heaviside independently proposed that radio waves are reflected back to Earth by a highly ionized region or layer in our outer atmosphere. Here we have the first link between geomagnetism and radio wave-propagation through their mutual dependence upon the ionosphere.

The original experimental determination of the ionosphere was made in 1925 by Breit and Tuve, of the Department of Terrestrial Magnetism, with the generous assistance of Taylor at the Naval Research Laboratory. They developed the pulse-and-echo technique which is now widely adopted for ionospheric studies. Simultaneously Appleton and Barnett in England obtained independent evidence of the ionosphere with a wave-interference method. The active interest of the Department in the subsequent development and application of ionospheric research has been maintained largely because of the important contributions to knowledge of the Earth's magnetic field which are made possible by this method of attack.

Radio apparatus provides our only means of exploring the ionosphere, which extends from about 40 to 400 miles above the Earth. Short pulses of radio-frequency energy are transmitted. These signals penetrate through the atmosphere until they encounter concentrations of ions and electrons of sufficient density to bend them around and return them to Earth. The recorder measures time-interval between signal and "echo." This provides values of virtual height of the reflecting region. For example, a signal reflected from a layer 100 km above the Earth travels an overall distance of 200 km, which requires transit time of just two-thirds of one-thousandth of a second (0.00067 sec).

Waves of higher frequency are more penetrating and require greater concentrations of electrons for reflection. Waves of still higher frequencies are not returned to Earth, since the ionosphere does not contain sufficient concentrations of charges to reflect these signals. Complete radio exploration of the ionosphere is accomplished with apparatus which automatically sweeps over a wide range of frequencies and pho-

tographically records the heights of the reflected signals. Equipment for this purpose has been developed by the Department, and the continuous operation of these units in the field is providing a solid foundation for detailed analyses of geomagnetic and related phenomena.

FIELD-OPERATIONS

The three complete automatic multi-frequency ionospheric recorders designed and constructed at the Department of Terrestrial Magnetism are now in continuous operation at the Huancayo (Peru) Magnetic Observatory, the Watheroo (Western Australia) Magnetic Observatory, and the College (Alaska) Observatory. This apparatus sweeps through a frequency-range from 16.0 to 0.516 Mc/sec and automatically records the apparent height of ionospheric echoes. One frequency-sweep is completed every 15 minutes. The apparatus consists of transmitter, receiver, control-units, recorder, and power-supplies. Transmitter and receiver are automatically interlocked so that no separate tuning of receiver is necessary. In effect, one variable oscillator is used for both transmitter and receiver.

The normal requirements for power under operating conditions amount to about one kilowatt. At the observatories in Peru and Australia, power is obtained from Diesel generators. These units provide direct current for operation of rotary converters which in turn supply alternating current for the radio apparatus. Each rotary converter is accurately controlled to a frequency of 60 cycles per second by means of a precise tuning-fork. Similar provisions for independent power are made at the College Observatory, although the commercially available power-supply has been found to be generally satisfactory. The installation at each observatory oper-

ated continuously throughout the report-year except for minor interruptions necessary for maintenance and adjustments to the apparatus. The equipment at Huancayo has been operating since November 1937, the recorder at Watheroo since May 1938, and the apparatus at College since June 1941.

ANALYSES OF DATA

In general, the results of recordings at each observatory indicate trends which parallel the present downward trend of the cycle of sunspot-activity. The E -, F_1 -, and F_2 -region critical frequencies at Huancayo and Watheroo observatories are slightly lower than during 1940. This downward trend is expected to continue for another year or two. Analyses show that average annual electron-density of the F_2 -region measured at noon at Huancayo Magnetic Observatory was about 50 per cent greater during the years of maximum numbers of sunspots (1937 and 1938) than during 1941.

Publication of detailed summaries of ionospheric data was discontinued early in 1942. This action was taken following specific request by governmental agencies, in view of important applications of ionospheric data to war problems.

Following is a discussion of ionospheric recordings during several intense magnetic storms:

March 1, 1941. The ionospheric conditions during the magnetic storm of March 1, 1941 were discussed in some detail in the last annual report. Further analyses have shown an unusual effect which was not remarked in earlier analyses. Following the conclusion of the severe magnetic disturbance, at about 23^h 30^m GMT, March 1, electron-densities in the F_2 -region of the ionosphere decreased very rapidly and simultaneously at both Huancayo and Watheroo. At 05^h 00^m GMT, March 2, the F_2 -layer critical frequencies at both locations averaged more

than 5 Mc/sec below the normal mean hourly value. After 05^h 00^m a recovery in the direction of normal was noted. This recovery was rather gradual, reaching normal values about 12^h 00^m GMT, March 2. Since ionospheric characteristics at widely separated points such as these frequently show no direct relationships, it is felt that an occurrence of this nature is worthy of especial note. The extent of the subnormal ionization recorded at each observatory would seem to preclude any possibility of its being a mere coincidence. This view is substantiated by the facts that the decrease in each case started after the end of the storm, the minimum values were reached simultaneously, and the trends back to normal, as well as the times of reaching normal, were in complete agreement.

July 4-5, 1941. It will be recalled that the magnetic storm of July 4-5, 1941 was relatively mild from 03^h 45^m GMT, July 4, to about 05^h 00^m, July 5. The period of greatest disturbance was recorded between 05^h 00^m and 24^h 00^m, July 5, the interval around 17^h 00^m being the most disturbed. At Huancayo and at Watheroo the ionospheric disturbances during the initial phase of the storm were relatively insignificant. At 05^h 00^m GMT, July 5, however, electron-densities at Huancayo took a sharp drop to subnormal values. For the duration of the disturbance electron-densities were far below normal, and it is again interesting to note that the lowest values were recorded several hours after the ending of the magnetic disturbances. Normal conditions were reached about 12 hours after the end of the magnetic storm.

At Watheroo electron-densities jumped to values well above normal at 05^h 00^m GMT, July 5, but immediately dropped off and continued at subnormal levels for the period of the disturbance. As at Huancayo, so at Watheroo ionospheric conditions did not return to normal until about 12 hours after the end of the storm. The relative degree of disturbance, however, was much smaller at Watheroo than at Huancayo.

September 18, 1941. Detailed comparisons of ionospheric effects at the observatories

during the magnetic storm of September 18–19, 1941 were handicapped to some degree by the severity of the disturbance, which produced complete disappearance of echoes for several hours at Huancayo. In general, the recordings at Huancayo showed extensive oscillations and rapid changes in maximum electron-density of the F_2 -region. These changes were sufficient to produce peaks and troughs above and below normal values. However, the extent of deviation from normal was not considered especially significant on September 18. Probably the most important feature at Huancayo was the recording of abnormally high electron-densities between 12^h 00^m and 24^h 00^m GMT, September 19. During this interval critical frequencies of the F_2 -region were frequently as great as 4 Mc/sec above the normal value.

At Watheroo ionospheric conditions were not greatly disturbed on September 18 except for a short period around 12^h 00^m GMT, when abnormally high electron-densities were recorded. For all of September 19, however, F_2 -region electron-densities were below normal. During the first 9 hours of September 19 critical frequencies were more than 3 Mc/sec lower than average. After the end of the disturbance a downward trend continued for several hours before the recovery-phase. Normal conditions apparently were reached about 8 hours after the end of the storm.

March 1, 1942. Preliminary analyses of ionospheric conditions during the moderately severe magnetic disturbance of March 1, 1942 have been undertaken. Unfortunately the records at Huancayo are not complete for the interval, because of maintenance and adjustments to the apparatus. No definite remarks may therefore be made concerning the ionospheric reaction at Huancayo during this disturbance. At Watheroo, however, F_2 -region electron-densities were subnormal prior to the commencement of the storm, at 07^h 30^m GMT, March 1. The increase in magnetic disturbance was associated with a rapid increase in electron-density to a peak at about 13^h 00^m. This was followed by a gradual downward trend to normal values, which were maintained for the duration of

the storm. The disturbance ended about 05^h 00^m, March 2, following which the characteristic drop to low values and the gradual rise back to normal was observed. It will be recalled that this same effect has been noted following other periods of magnetic disturbance. No unusual ionospheric effects were noted which might form a basis for further examination in view of the pronounced decrease in cosmic-ray intensity which was reported (see Year Book No. 41, pp. 94-95).

RADIO FADE-OUTS

The sudden ionospheric disturbances which produced short-period radio fade-outs at Huancayo and Watheroo during the calendar year 1941 are shown in tables 2 and 3. No significance is attached to the

TABLE 2
FADE-OUT SUMMARY, HUANCAYO MAGNETIC
OBSERVATORY, 1941

DATE	75° WEST MERIDAN TIME OF			MAXI- MUM ABSORP- TION (Mc/sec)
	Start	End	Maxi- mum	
	h m	h m	h m	
April 3	10 45	11 30	11 00	*
July 3	11 00	12 15	11 45	*
July 5	10 45	12 15	11 30	*
July 8	10 45	11 45	10 45	*
August 20	10 57	12 08	11 53	6.1
October 30 . . .	17 15	18 45	18 00	1.3
December 26	09 49	10 46	10 05	9.5

* Maximum absorption not reported.

fact that Watheroo recorded nearly twice as many fade-outs as did Huancayo. Magnetic records during these occurrences were examined for unusual pulses or bays, which are frequently associated with the ionospheric disturbances. No significant coincidences were noted during the preliminary investigation. This is probably because most of the fade-outs were relatively mild and many occurred during magnetically disturbed periods, which

mask out the small magnetic effects associated with fade-outs.

TABLE 3

FADE-OUT SUMMARY, WATHEROO MAGNETIC OBSERVATORY, 1941

DATE	120° EAST MERIDIAN TIME OF			MAXIMUM ABSORPTION (Mc/sec)
	Start	End	Maximum	
	h m	h m	h m	
January 30...	12 45	13 45	13 08	4.3
February 28..	07 45	09 30	08 00	4.0
February 28..	17 30	18 15	17 45	>9.0
March 3.....	16 30	17 00	16 40	5.0
July 1.....	12 30	13 55	13 10	2.4
July 2.....	10 25	11 30	10 57	4.8
July 9.....	10 45	11 50	11 40	2.0
August 2.....	08 30	13 00	09 00	2.05
September 15	13 15	14 15	14 00	2.7
September 18	10 15	11 10	10 30— 11 00*	>7.5
September 19	09 30	10 20	09 30— 10 15*	>4.0
September 20	10 30	11 35	10 30— 11 30*	>6.3
September 21	10 30	11 05	10 30— 11 00*	>6.7
September 23	10 00	11 05	10 00— 11 00*	>7.0
November 24	08 45	10 45	09 45	2.1

* No echoes during this period.

DEVELOPMENTAL AND EXPERIMENTAL WORK

Practically all instrumental developments and experimental work were carried out in connection with war work and in cooperation with our armed services.

The automatic camera for recording of aurora at the College Observatory was completed. Tests of this unit at temperatures down to 20° F below zero were conducted in the low-temperature rooms of the National Bureau of Standards. Since installation at College, this recorder has been in continuous operation. Preliminary reports from the Observatory indicate that

high correlation between auroras observed directly overhead and significant ionospheric phenomena may be expected.

The constant-voltage controllers for use at observatories were tested on the main generator at the Department. These units are now in operation at the observatories, and the high degree of constancy of voltage obtained by their use has resulted in improved recording.

COOPERATIVE ACTIVITIES

The unique position maintained by this Department as a result of the development and continuous operation of automatic multifrequency ionospheric equipment at several field-stations resulted in numerous requests for ionospheric data from federal agencies and from our allies. Special arrangements to insure the prompt handling and early distribution of such material to authorized agencies were undertaken. The data play an important role in estimates of world-wide ionospheric distribution, knowledge of which is essential in consideration of radio wave-transmission problems.

PUBLICATIONS AND PAPERS

The Department was represented at the Winter (1941–1942) Convention of the Institute of Radio Engineers in New York City by Wells, who presented a paper on "Ionospheric investigations at Huancayo Magnetic Observatory (Peru) with application to wave-transmission conditions." Following a brief description of the principle and design of the automatic multifrequency ionospheric equipment developed by the Department, the results of continuous observations at Huancayo were discussed in some detail. These results are representative of average ionospheric conditions in equatorial regions. Such regions play an important part in long-distance

radio communications. Typical variations from day to night conditions, as well as season-to-season changes, were discussed. The effect of such ionospheric changes upon selection of communication-frequencies was also emphasized. Normal recordings and the effect of magnetic disturbances upon the ionosphere were discussed. Methods of development and application of transmission-graphs were demonstrated. Such graphs make possible the conversion of the ionospheric data obtained at vertical incidence into radio wave-propagation information at oblique incidence over various distances. The *E*-layer is capable of supporting radio transmission over distances approaching 1500 miles, and the normal limit of single-hop transmission via the *F*-region is somewhat greater than 2000 miles.

Recordings of the frequency-separation between doubly refracted wave-components in the *F*-region at Huancayo were analyzed in terms of the intensity of the Earth's magnetic field at the level of maximum electron-density in the ionosphere.

A paper entitled "Earth's magnetic field and actual heights in ionosphere" was presented by Wells at the annual meeting of the American Geophysical Union in April 1942. A radio wave propagated into the ionosphere becomes divided into separate wave-components of different polarizations under the influence of the Earth's magnetic field. This is similar to the Zeeman effect observed when an electromagnetic wave is propagated in an ionized medium in the presence of a magnetic field. The separation in frequency between the individual wave-components provides a measure of the intensity of the Earth's magnetic field at the *actual* height in the ionosphere from which the signals are being returned. From separate records at Huancayo of critical frequencies of both ordinary and extraordinary wave-compo-

nents, mean hourly values of the frequency-separation over 4 months were used to obtain mean hourly values of magnetic field-intensity, H , in the ionosphere at the height of maximum electron-density. A plot of these values reveals a form of diurnal variation for H . Since H is measured at the height of maximum electron-density, it must be assumed that the diurnal variation in H , as observed by this technique, is a result of the change in actual height of the region of maximum electron-density of the ionosphere. Assuming the Earth to be a uniformly magnetized sphere, the variation of H with height above the Earth may be calculated. This provides means for conversion of values of H as observed from the ionospheric measurements into terms of actual heights. The diurnal curve obtained is similar to the diurnal curve of ionospheric heights obtained independently by other means. The technique outlined is particularly applicable at the magnetic equator. With specially developed apparatus, probably a single observation could be used to obtain accurate measurement of the intensity of the Earth's magnetic field in the ionosphere.

Wells addressed the Institute of Radio Engineers at Cleveland, July 1, 1942, on "Effect of solar activity on the ionosphere and radio communication." Severe disturbances in the ionosphere are produced by unusual solar activity and in turn directly influence radio communication. Solar flares or sunspot-eruptions have been definitely identified as the origin of short-period radio fade-outs. The ultraviolet radiation associated with the solar flare immediately produces intense ionization in the lower part of the ionosphere, which results in complete absorption of all normal sky-wave radio transmission. Disturbances of this nature seldom last

longer than one hour. The most severe radio disturbances, however, coincide with intense magnetic storms—storms frequently associated with active sunspot-areas. It is generally believed that streams of corpuscles are projected from active sunspots, travel to the Earth in one to four days, and produce magnetic storms, auroral displays, and radio disturbances. The severe disturbances can disrupt normal radio communications for several days and interrupt wired circuits. The effect of

magnetic disturbances on radio communication is more pronounced as the wave-path approaches the higher latitudes. Ionospheric recordings, by both the fixed-frequency and the multifrequency techniques, provide fundamental information regarding the development and effect of such disturbances on radio communications.

Valuable reports, compilations, and summaries of the data obtained from the records made at College were prepared by Bramhall and Seaton.

MAGNETISM AND ATOMIC PHYSICS

Tuve, Hafstad, Roberts, and Abelson of the nuclear-physics group were assigned during the entire report-year to war-research activities. Until August 1941, Heydenburg, Meyer, and L. Schmidt were engaged full time in improvement of the Atomic-Physics Laboratory, but they were then assigned for most of the time to war work using the one-million-volt generator. G. K. Green was in charge of the development of the cyclotron until March 12, 1942, when he began active duty as lieutenant in the United States Signal Corps. From then on he generously devoted his scant spare time to assuring continuity of the work ably carried on by Cowie (assigned from the National Cancer Institute), who with Ksanda, P. A. Johnson, Buynitzky, and Caherty was engaged on the cyclotron throughout the report-year. These men had the assistance of F. R. Nichols (to September 1941) and McCaw (from October 13, 1941 to June 3, 1942, when he joined the United States Army). The assignment of Research Fellows N. M. Smith, Jr., and J. A. Van Allen to war problems was continuous from July 1, 1941. Despite this depletion of personnel, good progress was made.

ATOMIC-PHYSICS OBSERVATORY

During the last few months in 1941 and January and February 1942, Meyer and Schmidt spent part time in further construction work on the Atomic-Physics Observatory. The accelerating tube had been removed from the generator in 1940 and an effort was made to boost the voltage on the generator by making certain changes in the design of the supporting column of the high-voltage cap. These changes were found to give no substantial improvement in the voltage, however, and the limit of the generator without the accelerating tube remained at 4.5 million volts.

Tests were made in the spring of 1941 on various accelerating-tube designs in an effort to build a tube that would withstand 4.5 million volts without breakdown. Working with an 8-foot test-section, a design was found using the original tube porcelains which gave an improvement of 50 per cent over the old tube. In July 1941 the construction of the many electrode-parts was begun by Schmidt with part-time help by Meyer. The parts were completed in January 1942, and Meyer and Schmidt then assembled and aligned the tube in the

generator. The ion-source was made ready for a test of the tube with an ion-beam. At this time the upper power-belt-pulley assembly was redesigned to allow the tension of the belt to be more easily adjusted. No difficulty was found in obtaining an ion-beam down the tube, but further work will be necessary in the refinement of the focusing system of the tube before the beam will be usable for precise experiments.

CYCLOTRON

The main units of the 60-inch cyclotron are (1) the magnet, (2) the main vacuum-system, (3) the control-system, (4) the power-supplies, and (5) the radio-frequency circuits. (See Year Book No. 40, pp. 89-91, for statement regarding the Cyclotron Laboratory and the development of the equipment.)

Magnet. Measurements made soon after assembly of the 200-ton Armco magnet showed that the pole-faces were out of parallelism by 0.007 inch. With the squeezing out of the heavy oil-film applied to the machined surfaces of contact of the four top, bottom, and side members, this lack of parallelism is now within the limit set of 0.003 inch. The motor-generator has characteristics that allow exciting the coils, which were built by the General Electric Company for a power-input of 75 kilowatts, to 130 kilowatts. Tests to determine whether use of full capacity of the generator would overheat the coils showed it would be safe to energize them continuously with an input of at least 115 to 120 kilowatts.

Before the vacuum-chamber was installed, a careful search was made to find out if any serious inhomogeneities existed in the pole-pieces. This was done by means of a coil of many turns connected to a

fluxmeter. Within the "ion-working space" of 50-inch diameter any inhomogeneities found in the magnetic field were so small as to make it a question whether they were real or the result of experimental error. Any large blowhole in a pole-piece would produce a hole in the magnetic field which would ruin the various focusing characteristics of the cyclotron and make the attainment of large beam-currents impossible.

A record magnetic test was made to measure the magnetic field at the center of the vacuum-chamber and at several points on a radius up to 68 inches at various values of exciting current. With the full rated current of the generator, 600 amperes, the magnetic field in the center, with the vacuum-chamber in place including its filler-plates, is 17,400 gauss. The fringing-field curve was investigated for four different values of exciting current and has a shape favorable for withdrawing the ion-beam from the dees. Measurements of absolute value of the magnetic field were made with a flip-coil and fluxmeter standardized at the National Bureau of Standards. It was possible to make these measurements with an internal consistency better than 1 part in 500 and with an absolute accuracy of 1 part or less in 200.

For tests of the azimuthal symmetry of the magnetic field, twin flip-coils were constructed in such a way that one coil remains at the center of the magnet, while the other revolves on a constant radius. The two coils are mounted on a common shaft and will be connected in series opposition to the fluxmeter. For proper operation of the cyclotron it is necessary that the field be quite symmetrical azimuthally, this being the main reason for the close mechanical tolerances on the magnet and vacuum-chamber. Any small lack of symmetry can be compensated at least to a

first order by inserting the vacuum-chamber so that it is off center with respect to the magnet-poles. The vacuum-chamber position can be checked very precisely with respect to the pole-pieces, and the necessary position for proper magnetic-field requirements can be and must be reproduced accurately. The water-flow for the magnet was checked and the controlling switches were set so that a flow of 3600 gallons of water per hour is required to close them.

Main vacuum-system. The main vacuum-system, which includes the vacuum-chamber, dee-tanks, pumps, and various appurtenances, was completed and thoroughly tested and all leaks were eliminated. The four 8-inch oil-diffusion pumps were found to have a pumping speed of about 2000 liters per second when ordinary Cenco Megavac oil was used. The baffle-systems for these pumps were designed and installed, as well as appropriate vacuum-valves and manifolds. The final test of the brass target-box shows it to be free of leaks.

The various components, including target-box, vacuum-chamber, cones, cylinders, main manifold, pumps, baffles, and valves, after individual tests, were assembled, and, although there were almost 200 separate rubber-gasket seals, a vacuum of 5×10^{-6} mm of mercury was obtained within a few hours.

The system was dismantled following this test, and the main vacuum-chamber was withdrawn from the magnet for the installation of the liners and for inspection and cleaning before final assembly. The pump-out lead was installed in the bottom of the vacuum-chamber, and assembly of copper-liners, radio-frequency connectors, dees, and dee-capacity compensators is under way.

Before the deflector-dee was designed, the path of an ion in the magnetic field when

subjected to various electrostatic deflections was calculated. By means of the deflector-electrode an intense transverse electrostatic field is set up across the path of an ion emerging from the slot in the deflector-dee. This field gives the ion a radial component of velocity which starts the ion in a path across the fringing-field and allows the ion to enter the target-box, the fixed openings of which must be cleared by the ion if it is to strike the target. With the attainable magnetic field, energies of approximately 25 million electron-volts (MEV) with deuterons and 50 MEV with protons are possible. Solution of the differential equations of the ion-path is difficult because the inherent empirical data cannot be expressed in any simple form. These empirical data are the shape of the fringing-field of the magnet and the strength of the varying electrostatic field of the deflector-electrode. A numerical integration was set up and Miss Lange calculated the points of the ion-path for a deuteron of 21.6 MEV subject to deflector-potentials of 120,000 volts and 150,000 volts. The resulting paths show that it will be feasible to bring out a 21- or 22-MEV deuteron-beam with about 120,000 volts applied to the deflector-electrode. The shape of the wall of the deflector-dee was designed to conform with the curves given by the numerical integration.

Control-system. The control-desk and the relay-box on the control-room wall are essentially complete. Minor schematic diagrams of the control-system wiring were made.

Power-supplies. The ion-source requires two power-supplies, (1) to light the filament, and (2) to create the arc from the ion-source filament to the ion-source cone. The latter emission-supply was completed. It consists of a three-phase bridge-rectifier in which the power-transformers are pre

ceded by a constant-current network of chokes and condensers; it delivers an essentially constant current independent of load-impedance. The current is varied by switching in condensers. The filament of the ion-source will be powered by a small motor-generator set mounted on top of the magnet.

The deflector-electrode is supplied by an air-insulated voltage-doubler rectifier capable of output-potentials from 0 to 200,000 volts. This complete power-supply was installed in a wire-mesh cage to insure protection of personnel. The test of this unit showed it to be perfect with the exception of a coronal breakdown on the 110,000-volt Westinghouse transformer.

Two power-supplies are required for the radio-frequency system. The first, which is completed, is a single-phase, 3000-volt, 1.25-ampere rectifier to supply the final stage of the exciter. The second, which is in construction, is a 200-kilowatt, three-phase, full-wave bridge-rectifier, utilizing six Federal Telegraph mercury-vapor rectifier-tubes, to furnish power to the plates of the final stage of the oscillators. The plate-transformer for this rectifier was installed in the power-room with a concrete curb cast around it with provision for draining any large leakage of oil from the transformer. A steel rack adjacent to the transformer will contain the rectifier-tubes, their filament-transformers, various protective equipment, and a blower controlled by thermostats.

All the power-supplies are enclosed in protective cages equipped with door switches which automatically disconnect the high voltage when a door is opened. Grounding chains will also be installed so that the output can be grounded by anyone working on the power-supply.

Radio-frequency system. The radio-frequency system is designed to have a master-oscillator, controlled by a crystal-driven

circuit or by stable inductance-capacitor circuits, the output of which is to be amplified by several stages of buffer-amplifier equipment driving the final radio-frequency amplifier. The final amplifier of the exciter is a large water-cooled tube to excite the grids of two water-cooled tubes in a push-pull circuit coupled by a transmission-line to the resonant circuit in the main vacuum-system. The filament and grid-supporting structures, anodes, and water-jackets for these tubes were completed. The design of these tubes is along lines suggested by Smith and Ayer, of Radio Corporation of America. Difficulty is being experienced in obtaining satisfactory insulators to support the grid- and filament-structures. These tubes are demountable and may be continuously pumped, so that they can be repaired quickly by installation of spare parts.

It is to be hoped that the instrument can be tuned up initially to produce a 100-microampere beam-current of 21 MEV deuterons. The radiation produced by such a beam is enormous, and will make necessary the installation of water-tanks and frequent radiation-surveys for the protection of personnel operating the cyclotron and occupying other parts of the laboratory.

MISCELLANEOUS

The reduced staff and the work of design and construction of the cyclotron prohibited any extended nuclear-physics research or completion of manuscripts on work already done.

Cowie found time, however, to cooperate with Drs. Voegtlin, Thomson, and Johnson, of the National Cancer Institute, in an investigation, still in progress, of chemotherapeutic effects of radioactive arsenic on liver tumors.

Cowie was coauthor with Colonel A. A. de Lorimier, of the Army Medical School,

and Dr. T. N. White, of the National Cancer Institute, of two reports to be published in the *American Journal of Roentgenology*. The titles are as follows: "Radiation hazards during roentgenoscopy," by T. N. White, Dean B. Cowie, and A. A. de Lorimier; "Protective features provided with the U. S. Army field X-ray equipment," by A. A. de Lorimier, Dean B. Cowie, and T. N. White. Cowie attended a meeting of the National Advisory Committee on X-Ray and Radium Protection at the Army Medical Center, Walter Reed Hospital, June 13, 1942, at which these subjects were discussed.

An article on a new type of radiation cell for the manipulation of radium was prepared by Drs. A. H. Dowdy and B. Du Bilier, of the Strong Memorial Hospital of the University of Rochester, and Cowie. This paper was accepted for publication in the *American Journal of Roentgenology*.

THEORETICAL-PHYSICS CONFERENCE

The Eighth Annual Washington Conference on Theoretical Physics was held April 23-25, 1942, in Washington, D. C., under the joint auspices of the Carnegie Institution of Washington and the George Washington University. The subject, "The problems of stellar evolution and cosmology," was essentially the further development of discussions at the conference of 1938 on "Problems of stellar energy-sources." There seems hardly any doubt that the so-called "carbon cycle," then proposed by Bethe, actually represents the source of energy for our Sun and for all other stars of the "main sequence" and that the energy-source of the so-called "red giant stars" lies in the thermonuclear reactions of lithium, beryllium, and boron, as was proposed by Gamow and Teller.

The problem of stellar evolution, that is, of changes with time in the observable

characteristics of a star, still presents serious difficulties, particularly in its application to the "red giants." Study of the so-called "shell-model" of a star proposed by Gamow in the 1938 conference was considerably advanced during the last year by Chandrasekhar and Schoenberg, who reported their results at the first session of the Eighth Conference.

On the question of the "mixing-up" process in a stellar interior, Randers reported his calculations of the convection-processes in rotating stars.

The problem of the correlation of various theoretical viewpoints on stellar evolution and the observational facts on the relative abundance of stars of various types was discussed. Shapley gave a general survey of the observational evidence. To correlate the theoretical picture of stellar evolution with the observational material, it is necessary to take into account the stellar population in various parts of the universe.

The second problem of the conference was that of the expanding universe and the related question of the origin of chemical elements during the early stages of the expansion. There is still considerable disagreement among investigators as to whether our universe is an expanding one. Consideration of the several estimates of the age of the universe indicated that the problem of the expanding universe must await more information regarding the evolutionary history of separate nebulae.

Thomas reported his attempt to explain the red-shifts in the spectra of distant light-sources as resulting from the interaction of the traveling light-quanta with the free electrons in interstellar space.

The attempts to explain the observed relative abundance of various chemical elements in the interiors of various stars have followed two different directions. It is suggested: (1) that the present abundance arises from some kind of chemical equi-

librium between various nuclei at certain high temperatures and densities; (2) that the origin of elements is a breaking-up process similar to the recently discovered process of uranium-fission. Both points were discussed and it was agreed that the second view is the more probable. Chandrasekhar reported on the "equilibrium-theory." Some details of a breaking-up process of the heavy fragments of primary nuclear matter which would finally lead to the ordinary nuclei of the known stable elements were discussed by Teller.

During the third day fundamental problems of physical constants and the properties of elementary particles were discussed. Teller criticized Dirac's recently expressed view that the number of elementary particles in the universe and also the value of the gravitational constant are slowly changing with time. Assuming Dirac's hypothesis, he would expect large changes

in the luminosity of the Sun, which is contrary to geological evidence.

Thomas presented his recent attempt to build up a formalism for consistent quantization of the electromagnetic field which would eliminate the difficulties inherent in the infinite self-energy of elementary particles.

Pauli discussed the theory of the "mesotron" on the assumption of zero-spin and concluded that this assumption is not satisfactory.

Twenty-six investigators from fifteen universities and research organizations took part in the conference. Several leading nuclear physicists and astronomers who had also accepted invitations to take part could not do so because of urgent unexpected demands of war problems. (A more detailed account of the conference is published in *Science*, vol. 95, pp. 579-581, 1942.)

FIELD-WORK AND REDUCTIONS

LAND MAGNETIC SURVEY

Additional material for the volume in the series of Researches of the Department of Terrestrial Magnetism on "Land Magnetic Survey, observations, 1927-1940" was prepared. The manuscript, by J. W. Green, Fleming, Vestine, and Wallis, is now ready for the preparation of the master copy for publication by the offset method.

Various governmental and private organizations were supplied with tabulations of magnetic data, geographical positions and descriptions of stations, and local maps for Africa, Australia, New Zealand, the Pacific islands, Central America, North America, South America, and the polar regions. Revisions were made of the computations of results obtained in the field by the United States Antarctic Expedition of 1940-1941 and the Louise A. Boyd Arctic Expedition of 1941.

The Department cooperated, through the loan of field-instruments and equipment to six observatories, to magnetic surveys in South Australia, Northern Australia, New Zealand, British East Africa, and the United States, as well as to the Boyd Arctic Expedition. International magnetic standards and corrections thereto for field-instruments were maintained as heretofore in cooperation with the United States Coast and Geodetic Survey at the Cheltenham Magnetic Observatory, where CIW sine-galvanometer 1 and CIW Schultze earth-inductor 48 are used as instruments to control these standards.

FIELD-OPERATIONS AND COOPERATIVE SURVEYS

Africa. Dr. A. Walter, Director of the British East African Meteorological Service, using

CIW magnetometer and inductor 13, continued active cooperation with the Department. In addition to the occupation of stations reported previously, he secured repeat-observations at the Seychelles and at Arusha, Tanganyika Territory, in October 1941. Observations at Kabete, Nairobi, were discontinued during February to September but were resumed in October 1941. Dr. Walter reports that every effort was made during the report-year to obtain monthly observations at Kabete to check secular variation. During 1942 he expected also to reoccupy stations at Fort Hall, Nanyuki, Naivasha, Gilgil, Equator, and Nakura in Kenya.

At Hermanus Observatory, where the secular variation of the Earth's field is very large, Dr. A. Ogg, of the Magnetic Branch of the Trigonometrical Survey of the Union of South Africa, obtained measurements at frequent intervals using CIW magnetometer-inductor 17. Through Dr. Ogg were received also the annual values for the observatory at Elisabethville and recent charts of magnetic declination with estimates of secular change for the Belgian Congo.

Australia. The personnel of the Aerial, Geological and Geophysical Survey of Northern Australia of the Australian Department of Mines has been banded together for the duration of the war at the Commonwealth's Department of Supply and Development at Canberra. The survey originally planned using CIW magnetometer-inductor 18 was completed. According to a report on August 12, 1942 from Chief Geologist J. M. Rayner, the original project for the continuation of the isogonic map of Australia, "based almost entirely on the observations made by the Department of Terrestrial Magnetism," was greatly extended during the course of the reductions, and isogonic maps going far to the north and east of Australia were prepared. These included isoporic charts for recent epochs.

The latest corrections in standards for CIW magnetometer 6 and dip-circle 226, on loan for survey-operations to the Adelaide Observatory of South Australia, were compiled and forwarded to Astronomer G. F. Dodwell,

who is compiling the results of observations made with them by his staff.

New Zealand. The Department cooperates with the New Zealand Magnetic Survey of the New Zealand Department of Scientific and Industrial Research through the loan of CIW magnetometer-inductor 27. Director H. F. Baird reports that by March 1942, despite the extension of the war, well distributed CIW repeat and new stations totaled 55, and that 7 more would be completed in March. These results are especially needed for the investigation of secular changes and the preparation of isoporic charts for the past decade.

Dr. E. Marsden, Secretary of the New Zealand Department of Scientific and Industrial Research, used a newly developed CIW instrument to make magnetic measurements in the Pacific Ocean and New Zealand.

North, Central, and South America. CIW magnetometer-inductors 26 and 28 were loaned to the United States Coast and Geodetic Survey for use in the Western Hemisphere on surveys (1) in the western United States and (2) in the Caribbean area and Central and South America, through arrangements made by the United States Department of State.

During the latter trip of 25,000 miles—95 per cent by air—56 stations, most of which were reoccupations of CIW stations, were occupied, as follows: Balboa and Coco Solo in the Canal Zone; Pinar del Río, Havana, Camaguay, and Santiago in Cuba; Kingston (Stony Hill), Woods, and Old Harbor in Jamaica; Port-au-Prince in Haiti; Puerto Plata and Ciudad Trujillo in the Dominican Republic; San Juan (Observatory) in Puerto Rico; St. Johns, Umbrella, Rat, and Henzell in Antigua; Port-of-Spain, Gordon, Harts Cut, and Junction in Trinidad; Georgetown, Bartica, and British Guiana 114 in British Guiana; Vassouras (Observatory), Rio de Janeiro, Bahia, and Belem in Brazil; Montevideo in Uruguay; Barcelona, Caracas, Ciudad Bolívar, Barquisimeto, Valera, and Maracaibo in Venezuela; Barranquilla, Cartagena, Medellín, Pleyades, Puerto Colombia, and

Bogotá in Colombia; San José and Uvita Island in Costa Rica; Teoloyucan, Ciudad del Carmen, and Chetumal in Mexico; Colon, Old Panama, and David in Panama; Corinto and Managuas in Nicaragua; Puerto Cortez and Tegucigalpa in Honduras; La Union and San Salvador in El Salvador; Guatemala City in Guatemala. Eight magnetic stations were subsequently occupied in Bermuda, following which the complete standardization of instrumental equipment was completed at the Cheltenham Magnetic Observatory.

Arctic. The Louise A. Boyd Arctic Expedition of 1941 (June to November), under the leadership of Miss Boyd on Captain Bartlett's schooner *Effie M. Morrissey*, obtained magnetic data using CIW magnetometer-inductor 16 and dip-circle 222. Instructions and compilations of data were prepared by the Department, and the observers were instructed in methods of observation and computation for magnetic and astronomical determinations. Control of in-

strumental constants and corrections on standards were effected at the Cheltenham Magnetic Observatory. The stations occupied, italics indicating repeat-stations, were: *St. John's* in Newfoundland; *Dundas Harbor* in North Devon Island; *Pond's Inlet*, Clyde River, Cape Searle, *Pangnirtung*, and York Sound (south side of Frobisher Bay) on Baffin Island; and *Hopedale* and *Battle Harbor* in Labrador. The expedition was under the scientific sponsorship of the National Bureau of Standards. Ionospheric characteristics as determined by special radio measurements, auroral conditions, and measurements of ultraviolet-light intensities were also included in the program. The magnetic results are valuable in a region where data are especially needed.

Miss Boyd supplied values of magnetic declination obtained on her East Greenland Expedition of 1938 at 4 stations on Jan Mayen Island, 1 in Spitzbergen, and 7 in eastern Greenland.

OBSERVATORY-WORK

Johnston was in charge of the Section of Observatory-Work. The reductions of magnetic data and computations in connection with the analysis of the magnetic results from the observatories were continued with the assistance of Scott and Miss Balsam. McNish and Torreson were engaged in war investigations throughout the report-year. McNish prepared a paper on "The aurora and geomagnetic storm of September 18-19, 1941." Wait discussed further the atmospheric-electric and meteorological data from Watheroo and Huancayo for the 11-year period 1924-1934; he and Torreson published a paper on these investigations. Wait continued to study the atmospheric-electric data for Watheroo and Huancayo and completed two additional papers, one on the effect of smoke on the Watheroo data, and the other on simultaneous atmospheric-electric observations over the oceans and at Watheroo.

The complete geomagnetic program was maintained at Watheroo and Huancayo observatories. At Watheroo, in cooperation with the Australian Commonwealth Department of Air, weekly summaries of ionospheric data, forecasts of conditions likely to affect short-wave radio transmission, and predicted values of maximum usable frequencies for various distances were prepared. The geomagnetic program at both observatories comprises continuous records of the three magnetic elements (*D*, *H*, and *Z*), positive and negative conductivity of the air, atmospheric potential-gradient at the surface, earth-currents in two directions at right angles with duplicate lines, heights of the ionosphere by fixed frequency and automatic multifrequency, daily spectrohelioscopic observations during the periods assigned by the International Astronomical Union, and the meteorological elements. A three-compo-

nent seismograph and precision cosmic-ray meter are also operated at Huancayo.

The Section continued the reduction of the magnetic data from Watheroo and Huancayo observatories. Final reductions were made for the year 1940 and preliminary compilations for the year 1941. The final values of the magnetic elements for all days during 1940 and the preliminary values for 1941 are shown in table 4.

The extensive program of reporting weekly the magnetic three-hour-range in-

duced indices K_r . The world-wide K_w is introduced in order to obtain an average of the reduced indices, in which K_r from high-latitude stations are given double and equatorial stations single weights. Individual indices from each of the seven American-operated observatories and the weighted mean index (K_w) are mailed out weekly by the Section to governmental agencies and other interested persons. K -indices and other cosmic data were published quarterly. In order to characterize

TABLE 4

ANNUAL VALUES OF THE MAGNETIC ELEMENTS AT THE WATHEROO AND HUANCAYO MAGNETIC OBSERVATORIES AS BASED ON MAGNETOGRAMS FOR ALL DAYS, 1940 AND 1941

YEAR	DECLINATION, <i>D</i>	INCLINATION, <i>I</i>	INTENSITY-COMPONENTS					LOCAL MAGNETIC CONSTANT, <i>G</i>
			Horizontal, <i>H</i> (γ)	Total, <i>F</i> (γ)	North-south, <i>X</i> (γ)	East-west, <i>Y</i> (γ)	Vertical, <i>Z</i> (γ)	
WATHEROO MAGNETIC OBSERVATORY								
1940.....	3° 15.8 W	64° 24.3 S	24700	57175	24660	—1406	—51564	35704
1941.....	3 12.2 W	64 25.1 S	24705	57216	24666	—1381	—51607	35723
HUANCAYO MAGNETIC OBSERVATORY								
1940.....	6 55.9 E	2 14.3 N	29517	29540	29302	3562	1154	29524
1941.....	6 50.3 E	2 13.6 N	29471	29493	29262	3509	1146	29477

dex K between 0 and 9 (Year Book No. 40, p. 99) was continued, in conformity with the resolution passed by the Association of Terrestrial Magnetism and Electricity of the International Union of Geodesy and Geophysics at its Seventh Assembly in September 1939. K -indices for the 7-day period ending Greenwich midnight on Friday are regularly transmitted to the Washington office both by our observatories and by the five magnetic observatories of the United States Coast and Geodetic Survey. The K -indices are assembled by the Section and standardized by means of keys for transforming K into

each day's succession of eight three-hour intervals by a single index with due allowance for the *actual* ranges experienced, the computation of daily indices B was continued and completed for the year 1941. Despite disordered world-affairs, correspondence with foreign observatories in regard to K -indices and character-figures (on scale 0, 1, and 2) was maintained. K -indices have been supplied by 12 observatories, namely (in order of geomagnetic latitude), Lerwick, Dombås, Meanook, Eskdalemuir, Rude Skov, Agincourt, Witteveen, Abinger, Niemegk, San Fernando, Zô-Sè, and Cape Town (Hermanus). The

K-indices for the second half of 1940 and first half of 1941 for these 12 magnetic observatories were tabulated. Those for the second half of 1940, together with summaries for the whole of 1940, were published. *K*-indices for the year 1940 for Sodankylä, Slutzk, Chambon-la-Forêt, Apia, Kuyper, Pilar, and Amberley were tabulated and are awaiting publication, as are also compilations of daily mean *K*-indices from 25 observatories (7 American-operated and 18 world-wide) for January to December 1940.

The Department and the United States Coast and Geodetic Survey, in cooperation with the communication-services of the United States Army and the United States Navy and several amateur radio stations, continued to supply the American half-day and whole-day magnetic character-figures (*C*₄) based upon the reports of the seven American-operated observatories. Whole-day magnetic character-figures (*C*) were assembled for those world-wide magnetic observatories reporting them.

Cooperation in the magnetic and atmospheric-electric programs of the Department was given by various magnetic observatories. Our international magnetic standards were maintained at Cheltenham Magnetic Observatory, and the continuous recordings of atmospheric conductivity (positive and negative) and potential-gradient and of earth-currents were continued at the Tucson Magnetic Observatory; both of these observatories are operated by the United States Coast and Geodetic Survey.

The Section continued the reduction of the geomagnetic data from the Watheroo and Huancayo observatories. Final reductions were made for the year 1940 and preliminary compilations for the year 1941.

Compilations to make current the annual values of all the geomagnetic elements (*D*, *H*, *Z*, *I*, *X*, *Y*, and *F*) for the world's

magnetic observatories were begun by Ennis and completed by Scott after the former's death.

OPERATIONS AT OBSERVATORIES

Watheroo Magnetic Observatory, Watheroo, Western Australia. The Watheroo Magnetic Observatory is situated in latitude 30° 19'1" south and longitude 115° 52'6" east of Greenwich, 244 meters (800 feet) above sea-level.

The Eschenhagen magnetograph was in continuous operation. Weekly determinations of the values of the base-lines for the three elements were made in the absolute observatory. Control of the scale-value of the horizontal-intensity variometer was maintained by monthly determinations, using the method of magnetic deflections. Scale-values of the vertical-intensity variometer were determined daily by the electrical method.

The la Cour rapid-running magnetograph was in operation throughout the year. Determinations of scale-value were made at monthly intervals, using the electrical method. The monthly scale-values for both the Eschenhagen and la Cour magnetographs are shown in table 5.

The preliminary values for the annual changes in the magnetic elements during 1940.5 to 1941.5 are: declination, +3'6; horizontal intensity, +5 gammas; vertical intensity, -43 gammas; inclination, -0'8 (see table 4).

Numerous requests have been received for magnetic data, principally the values of declination at various points in the state of Western Australia, from the different branches of the defense services, and in order to supply this information in a suitable form, an isogonic map of Western Australia was prepared showing lines of equal magnetic declination for the year 1942; copies of this map have been furnished to the military authorities and to the Department of Lands and Surveys.

As in previous years, three-hour-range indices, *K*, were assigned from an examination

of the Eschenhagen traces and transmitted weekly to Washington through the Australian Commonwealth Department of Air.

There were 12 major magnetic disturbances during 1941; table 6 shows details of these storms, full descriptions of which were forwarded to Washington monthly.

The recording of earth-currents was continued; the system of electrodes and methods of registration will be found described in previous reports. The scalings and prepara-

made on days when meteorological conditions were favorable.

Positive and negative air-conductivities were also recorded continuously. From the tabulated hourly values of both potential-gradient and conductivity, certain days had to be excluded owing to adverse weather conditions or the smoke from bush-fires. Preliminary mean values of the atmospheric-electric elements are shown in table 7.

The automatic multifrequency ionospheric recording apparatus has functioned practically

TABLE 5

SCALE-VALUES OF MAGNETOGRAPHS, WATHEROO
MAGNETIC OBSERVATORY, 1941

MONTH	SCALE-VALUES IN γ /MM			
	ESCHENHAGEN		LA COUR	
	<i>H</i> (reduced to base- line)	<i>Z</i> (means of daily values)	<i>H</i>	<i>Z</i>
January...	2.38	3.34	4.61	2.98
February..	2.39	3.35	4.51	2.70
March....	2.38	3.36	4.44	2.82
April.....	2.39	3.33	4.47	2.97
May.....	2.40	3.35	4.47	3.26
June.....	2.39	3.21	4.42	3.20
July.....	2.39	3.23	4.44	3.26
August....	2.40	3.27	4.59	3.57
September	2.40	3.29	4.42	3.51
October...	2.43	3.30	4.56	3.24
November	2.40	3.34	4.51	3.06
December..	2.40	3.25	4.48	3.06

tion of monthly curves of diurnal variation were kept current; by this means electrode-faults or anomalies can be quickly detected. The earth-current recorder, being visual, has proved valuable in the early detection of the commencement of magnetic disturbances and gives a warning of disturbed conditions in the ionosphere.

Air-potentials were continuously recorded as in previous years. The reduction of the recorded values to the potential which would be recorded at a point 1 meter above a plane surface was controlled by series of eye-observations, using the stretched-wire method,

TABLE 6
DETAILS OF MAGNETIC DISTURBANCES RECORDED AT
THE WATHEROO MAGNETIC OBSERVATORY
DURING 1941

* DATE	RANGES		
	<i>H</i> (γ)	<i>D</i> ($^{\circ}$)	<i>Z</i> (γ)
January 3-4.....	85	14	59
January 24.....	107	24	135
March 1-2.....	658	77	>350
March 13-14.....	149	21	162
March 28-31.....	185	32	>194
April 24-25.....	148	22	144
July 4-7*.....	563	65	>215
August 4-5.....	168	26	195
September 18-19*.....	684	73	>336
October 31-November 1	173	19	149
November 27-28.....	148	18	129
December 1-2.....	147	29	202

* Aurora australis observed.

continuously throughout the year, the only interruptions being due to necessary maintenance, control-observations, adjustments, and minor repairs. The antenna-systems were serviced as required. Scalings and reductions have been maintained strictly current. Tables 8 and 9 show the mean hourly values of ionospheric data for 1941. The Australian Commonwealth Department of Air was supplied with weekly coded reports of ionospheric conditions and also, when necessary, warning of approaching conditions likely to affect high-frequency radio transmission. Predicted values of maximum usable frequency

over various distances of path were regularly supplied to the Department of Air. Ionospheric data were communicated to the Radio Research Board of the Commonwealth Council for Scientific and Industrial Research, the Chief Radio Inspector of the Postmaster-General's Department, and the (United States) National Bureau of Standards.

A regular watch was kept, using the Hale spectroheliometer, for solar activity, and re-

Scalings and reductions were maintained practically current until the end of 1941, when, owing to the great reduction in the staff, some of the scalings had to be postponed. Essential control-observations and reductions, however, were kept current.

W. C. Parkinson continued as Observer-in-Charge. McCarthy left on July 15, 1941, to go with the Radio Research Board; he was replaced by Norman (beginning July 1,

TABLE 7

PRELIMINARY MONTHLY MEAN VALUES OF ATMOSPHERIC-ELECTRIC ELEMENTS,
WATHEROO MAGNETIC OBSERVATORY, 1941

MONTH	POTENTIAL-GRADIENT			AIR-CONDUCTIVITY, UNIT 10^{-4} ESU				
	No. selected days	Reduction-factor	Value (v/m)	No. selected days	λ_+	λ_-	$(\lambda_+ + \lambda_-)$	(λ_+ / λ_-)
January.....	19	....	92.8	17	1.84	1.72	3.56	1.07
February.....	19	....	95.7	19	1.42	1.31	2.73	1.08
March.....	24	1.18	94.9	23	1.38	1.25	2.63	1.10
April.....	18	....	66.8	16	1.86	1.69	3.55	1.10
May.....	20	....	57.4	19	2.49	2.33	4.82	1.07
June.....	14	....	65.0	10	2.52	2.26	4.78	1.12
July.....	15	....	63.6	11	2.43	2.11	4.54	1.15
August.....	21	1.05	71.2	26	2.25	1.87	4.12	1.20
September.....	21	....	76.4	26	1.94	1.57	3.51	1.24
October.....	25	....	70.2	26	1.75	1.70	3.45	1.03
November.....	20	....	84.0	22	1.55	1.40	2.95	1.11
December.....	12	....	79.1	24	1.63	1.58	3.21	1.03
Totals and means.....	228	1.12	77.3	239	1.92	1.73	3.65	1.11

ports of the observations were transmitted monthly to Washington.

Observations of meteorological phenomena were made regularly as in previous years. Monthly summaries were supplied, as before, to the Commonwealth Weather Bureau, and, in addition, on and after January 9, 1942, telegraphic coded weather-reports were prepared and transmitted at 09^h, 12^h, and 18^h daily (120° east meridian time) to the Divisional Forecasting Offices of the Department of Air at Perth and Geraldton. Table 10 shows rainfall at Watheroo during 1941.

1941). Muhling resigned on August 31, 1941, to enlist in the Australian Navy; Lucas left on January 29, 1942, to take up work at the University of Western Australia. On January 1, 1942, W. D. Parkinson was appointed as temporary part-time observer, the remainder of his time being occupied with work at the Observatory for the Department of Air. A mechanic and assistant mechanic are regularly employed. The general hand who left in January 1942 could not be replaced because it was impossible to obtain an able-bodied man for the work.

TABLE 8
PRELIMINARY MEAN HOURLY VALUES OF IONOSPHERIC DATA,
WATHEROO MAGNETIC OBSERVATORY, 1941

120° east meridian time (h)	$h_{F_1}^{max}$ (km)	$h_{F_1}^{min}$ (km)	$h_{F_2}^{max}$ (km)	$h_{F_2}^{min}$ (km)	f_E^o (Mc/sec)	$f_{F_1}^o$ (Mc/sec)	$f_{F_2}^o$ (Mc/sec)	f_{min} (Mc/sec)
00.....	...	...	335	260	....	....	4.36	....
01.....	...	...	332	256	....	....	4.24	....
02.....	...	...	327	251	....	....	4.06	....
03.....	...	...	322	249	....	....	3.90	....
04.....	...	...	319	250	....	....	3.70	....
05.....	...	...	315	252	....	....	3.54	....
06.....	...	...	298	247	1.70	....	3.89	0.60
07.....	244	233	280	256	2.11	3.90	5.11	0.68
08.....	230	225	284	274	2.67	4.04	6.07	0.79
09.....	225	217	298	293	3.00	4.30	6.65	0.83
10.....	223	215	305	296	3.21	4.54	7.20	0.90
11.....	218	210	309	298	3.30	4.63	7.57	0.92
12.....	217	211	309	300	3.34	4.69	7.82	0.95
13.....	221	214	314	298	3.31	4.67	7.92	0.94
14.....	227	219	308	292	3.25	4.56	8.02	0.91
15.....	230	222	303	284	3.08	4.36	7.91	0.88
16.....	232	226	294	271	2.80	4.11	7.57	0.79
17.....	240	231	289	254	2.28	3.97	7.17	0.73
18.....	...	...	287	234	1.74	....	6.44	0.65
19.....	...	...	300	230	....	....	5.56	....
20.....	...	...	313	237	....	....	5.03	....
21.....	...	...	328	250	....	....	4.65	....
22.....	...	...	339	259	....	....	4.51	....
23.....	...	...	342	262	....	....	4.44	....

TABLE 9
PRELIMINARY MONTHLY MEANS OF HOURLY VALUES OF IONOSPHERIC DATA,
WATHEROO MAGNETIC OBSERVATORY, 1941

Month	$h_{F_1}^{max}$ (km)	$h_{F_1}^{min}$ (km)	$h_{F_2}^{max}$ (km)	$h_{F_2}^{min}$ (km)	f_F^o (Mc/sec)	$f_{F_1}^o$ (Mc/sec)	$f_{F_2}^o$ (Mc/sec)	f_{min} (Mc/sec)
January.....	233	226	343	300	2.83	4.44	6.19	0.76
February.....	233	226	336	289	2.95	4.29	5.65	0.77
March.....	230	219	316	266	2.75	4.33	6.07	0.75
April.....	227	220	295	250	2.57	4.28	5.84	0.73
May.....	225	216	283	239	2.56	3.98	5.16	0.70
June.....	224	215	280	236	2.55	3.85	5.00	0.72
July.....	230	219	285	244	2.63	3.98	4.78	0.83
August.....	224	218	294	248	2.69	4.30	5.16	0.87
September....	223	226	305	256	2.76	4.42	5.75	0.99
October.....	229	220	319	267	2.88	4.39	6.25	0.87
November....	239	230	332	287	2.87	4.36	6.30	0.94
December....	231	225	338	298	2.97	4.44	6.49	0.84
Means.....	229	222	310	265	2.75	4.26	5.72	0.81

Acknowledgment is gratefully made to various government departments for assistance, especially valuable under present conditions; particularly to the Department of Trade and Customs for their continued favorable action with regard to equipment and supplies entering the country, and also to the Wireless Branch of the Postmaster General's Department. The Signals Branch of the Department of Air has also been most helpful in transmitting magnetic messages weekly.

TABLE 10

RAINFALL AT WATHEROO MAGNETIC
OBSERVATORY DURING 1941

Month	Monthly total (in.)	No. days	Average for 24 years (in.)
January.....	0.00	0	0.34
February.....	0.88	2	0.56
March.....	0.05	3	1.04
April.....	1.83	12	0.92
May.....	2.36	8	2.17
June.....	3.76	16	3.39
July.....	1.89	17	2.95
August.....	1.43	11	2.21
September....	1.65	13	1.27
October.....	0.78	6	0.85
November....	0.66	6	0.33
December....	0.13	3	0.37
Totals.....	15.42	97	16.40

To the present reduced Observatory staff, who have labored under considerable disadvantages during the past report-year, great credit is due for the comparatively satisfactory condition of the work on June 30, 1942.

Huancayo Magnetic Observatory. The Huancayo Magnetic Observatory is situated about $8\frac{1}{2}$ miles about west of the town of Huancayo in the central valley of the Peruvian Cordillera. It is in latitude $12^{\circ} 02'7''$ south and longitude $75^{\circ} 20'4''$ west and at an altitude of 3350 meters (11,000 feet) above sea-level.

Practically all the Observatory's work is done by the use of automatically recording apparatus, most of which record photographi-

cally. Time-control marks on the records are made electrically by lights or mechanical devices operated by a master clock and program-machine which are frequently checked and adjusted through the use of radio time-signals. Except for the ionospheric recorder and the meteorological recorders, all instruments record intervals of Greenwich days, since traces are changed daily at 19^h , 75° west meridian time. Daily development of all photographic traces permits excellent control of instrumental equipment.

The magnetographs consist of two separate three-variometer units: an Eschenhagen and a rapid-run la Cour, both of which operated continuously during the year. A low-sensitivity la Cour *H*-variometer also recorded on the Eschenhagen magnetogram. Weekly absolute observations were made with magnetometer and earth-inductor for the control of base-lines. Scale-value determinations for the *H*- and *Z*-variometers of the la Cour magnetograph were made on or near the 15th of each month by the Helmholtz-coil method. Helmholtz-coil scale-value determinations were also made for the Eschenhagen magnetograph, once each week for the *H*- and *D*-variometers and three times a week for the *Z*-variometer.

Air-potentials were recorded continuously with the standard potential-gradient apparatus. Scale-values were determined once every two weeks and reduction-factors quarterly by comparisons with potentials measured on the standardization-plot near by. Positive and negative conductivities of the air were recorded continuously and scale-value determinations made every two weeks.

Earth-current potentials were recorded continuously on the Leeds and Northrup recording potentiometer for two separate systems of north-south and east-west pairs of electrodes.

The multifrequency ionospheric equipment operated with only minor breaks in continuity for maintenance and repair, except during a period in the latter part of February and the early days of March when two or more days of record were lost on three occasions because of instrumental difficulties. The fixed-fre-

quency equipment recorded regularly until the time of the difficulty in February, but was disconnected at that time and was only returned to operation in the latter part of June. Daily control-observations and checks were kept up consistently through the year and monthly calibrations were made. Compilations of the scaled values from the traces were completed within a few days of the month's end and the tabulations forwarded to Washington by air.

The program of daily morning meteorological observations was continued as in previous years, with recording instruments operating continuously in the meteorological shelter and in the atmospheric-electric and cosmic-ray buildings. Daily determinations were made of condensation-nuclei at a point near the meteorological shelter each morning at the time of the meteorological readings. The minimum temperature during the year was $-4^{\circ}.3$ C and the maximum was $24^{\circ}.6$ C; the lowest monthly mean minimum was $0^{\circ}.43$ C in July 1941 and the highest monthly mean maximum was $21^{\circ}.93$ in November of the same year. The rainfall from July 1, 1941 to June 30, 1942 totaled 32.36 inches, well above the average for previous years. As before, tabulations of meteorological data were supplied monthly to the Instituto Nacional de Meteorología e Hidrología (formerly Servicio Meteorológico Nacional del Perú), to the Centro Geográfica Departamental de Junín, and on several occasions to other governmental agencies and to private persons interested in the climate of the Sierra.

Cosmic-ray meter model C no. 2 recorded continuously with only minor losses of trace. The weekly checks of high-potential balance and of the electrometer zeros were continued.

During the month of June 1941, Ledig was able to be of assistance to the cosmic-ray expedition of Dr. Arthur H. Compton and his associates Drs. Wollan, Hughes, and Hilberry. Help was given them in connection with the diplomatic procedure of obtaining free entry for their scientific equipment of 95 cases. The personnel were acclimated to the high altitude of the Andes by visits at the

Observatory before leaving for Mahr Tunnel and San Cristobal mine (in Peru), where Wilson cloud-chamber observations were made at an altitude of over 15,000 feet. On June 25, Ledig went by plane to Arequipa and thence to Mollendo by automobile with Dr. Hilberry. He assisted until June 30 (when he returned by plane to Huancayo) in passing the equipment through the customs and in unpacking and assembling it, preparatory to Dr. Hilberry's ascent of El Misti (19,000 feet). Ledig's son Paul accompanied Dr. Hilberry as interpreter and general assistant on the ascent of El Misti, where records were obtained with a Wilson cloud-chamber.

Two Wenner horizontal-component seismometers and a Benioff vertical-component seismometer recorded satisfactorily through the year. Analyses were made of all important seismic disturbances and forwarded with the monthly journals, and 23 of these were sufficiently important to be sent in the international seismic code with the weekly broadcast of magnetic data.

Daily observations of the Sun with the Hale spectrohelioscope were made as weather-conditions permitted, at the assigned observational periods. Though only six times during the year were there seen activities on the Sun that merited careful description, monthly reports were prepared and transmitted to Washington.

Although the weekly broadcast of scientific data was ordered discontinued in January 1942 by the Departamento General de Radiotelegrafía del Perú, consideration of the Observatory's case permitted a reinauguration of this service in March.

The preliminary values for the annual changes in the magnetic elements during 1940.5 and 1941.5 are: declination, $-5^{\circ}.6$; horizontal intensity, -46 gammas; vertical intensity, -8 gammas; inclination, $-0^{\circ}.7$ (see table 4).

Preliminary monthly mean values of the atmospheric-electric results for the year 1941 are given in table 11, and the mean hourly values of ionospheric data and their monthly means for 1941 are listed in tables 12 and 13.

As always, the Observatory has enjoyed the confidence and friendship of the local Peruvian population, and there has been evidence of an increased interest among all Peruvians in learning something of the work. There were occasional visitors from the American colony in Peru as well as British and American travelers in the country. Assistance by the United States Embassy to Peru in obtaining free entry for equipment and supplies is gratefully acknowledged, and sincere

tion of all members of the staff made possible the successful continuance of the extended geophysical program.

College Observatory, Alaska. In pursuance of a comprehensive geophysical program, the Department maintained in cooperation with the University of Alaska at College, Alaska, a complete magnetic, auroral, and ionospheric observatory. This Observatory is in the zone of maximum auroral activity, about 5 miles west of Fairbanks, in latitude $64^{\circ} 51.4$ north,

TABLE 11

PRELIMINARY MONTHLY MEAN VALUES OF ATMOSPHERIC-ELECTRIC ELEMENTS,
HUANCAYO MAGNETIC OBSERVATORY, 1941

MONTH	NO. SELECTED DAYS	POTENTIAL-GRADIENT		AIR-CONDUCTIVITY, UNIT 10^{-4} ESU			
		Reduction- factor	Value (v/m)	λ_+	λ_-	$(\lambda_+ + \lambda_-)$	(λ_+ / λ_-)
January.....	3	....	65.1	3.30	3.01	6.31	1.10
February.....	3	....	87.2	2.63	2.20	4.83	1.20
March.....	3	....	53.1	3.43	3.57	7.00	0.96
April.....	5	....	39.9	4.19	4.77	8.96	0.88
May.....	8	....	48.3	3.91	4.29	8.20	0.91
June.....	9	....	48.0	4.60	4.79	9.39	0.96
July.....	16	1.17	52.2	3.89	4.45	8.34	0.87
August.....	12	....	48.8	4.38	4.81	9.19	0.91
September.....	10	....	49.6	4.05	4.04	8.09	1.00
October.....	6	1.14	41.9	4.65	4.87	9.52	0.94
November.....	5	....	47.6	4.34	4.89	9.23	0.89
December.....	3	....	54.0	3.19	3.28	6.47	0.97
Totals and means...	83	1.16	53.0	3.88	4.08	7.96	0.97

appreciation is expressed for the support and cooperation of persons in positions of authority in the Peruvian government.

P. G. Ledig as Observer-in-Charge and M. W. Jones as observer were members of the scientific staff throughout the year. R. C. Coile resigned February 9, 1942 to join the American Army. He was replaced by A. A. Giesecke, Jr., on January 29. E. J. Chernosky arrived early in May to become the fourth member of the scientific staff. The clerical assistants, T. Astete, A. Macha, and V. Murga, continued to give excellent service in the reduction of data and general operation of the Observatory. The enthusiastic coopera-

longitude $147^{\circ} 49.3$ west, at an altitude of about 1250 feet (381 meters).

The insensitive la Cour magnetograph with accessory instruments for base-line and scale-value determinations was mounted on concrete piers housed in buildings occupied by the Second International Polar Year Expedition (October 1932 to March 1933) at the same location.

The magnetograph was in continuous operation from August 1, 1941. The scale-values of the variometers were 18.2 γ per millimeter for horizontal intensity, 27.4 γ per millimeter for vertical intensity, and 5.18 per millimeter for declination. Preliminary mean values of

TABLE 12

PRELIMINARY MEAN HOURLY VALUES OF IONOSPHERIC DATA,
HUANCAYO MAGNETIC OBSERVATORY, 1941

75° west meridian time (h)	$h_{F_1}^{max}$ (km)	$h_{F_1}^{min}$ (km)	$h_{F_2}^{max}$ (km)	$h_{F_2}^{min}$ (km)	f_E^o (Mc/sec)	$f_{F_1}^o$ (Mc/sec)	$f_{F_2}^o$ (Mc/sec)	f_{min} (Mc/sec)
00.....	...	...	318	260	....	....	6.79	....
01.....	...	...	313	260	....	....	6.08	....
02.....	...	...	312	263	....	....	5.36	....
03.....	...	...	310	268	....	....	4.70	....
04.....	...	...	311	273	....	....	4.13	....
05.....	...	...	316	278	0.78	....	3.74	0.64
06.....	...	...	317	269	1.59	....	5.13	0.72
07.....	261	245	322	262	2.44	4.35	7.65	0.87
08.....	250	231	368	304	2.92	4.67	8.99	1.08
09.....	237	225	419	328	3.36	4.81	9.40	1.30
10.....	227	220	448	352	3.63	4.88	9.23	1.46
11.....	221	217	454	369	3.80	4.90	8.93	1.62
12.....	219	214	457	374	3.85	4.90	8.78	1.66
13.....	218	213	457	373	3.77	4.86	8.86	1.61
14.....	223	213	452	362	3.60	4.81	9.10	1.51
15.....	236	216	444	343	3.25	4.71	9.33	1.29
16.....	260	226	442	316	2.80	4.54	9.47	1.12
17.....	...	...	429	262	2.28	....	9.49	0.90
18.....	...	...	420	281	1.30	....	9.34	0.73
19.....	...	...	441	314	0.84	....	8.75	0.66
20.....	...	...	422	316	....	....	8.28	....
21.....	...	...	385	295	....	....	8.06	....
22.....	...	...	357	279	....	....	7.73	....
23.....	...	...	333	266	....	....	7.26	....

TABLE 13

PRELIMINARY MONTHLY MEANS OF HOURLY VALUES OF IONOSPHERIC DATA,
HUANCAYO MAGNETIC OBSERVATORY, 1941

Month	$h_{F_1}^{max}$ (km)	$h_{F_1}^{min}$ (km)	$h_{F_2}^{max}$ (km)	$h_{F_2}^{min}$ (km)	f_E^o (Mc/sec)	$f_{F_1}^o$ (Mc/sec)	$f_{F_2}^o$ (Mc/sec)	f_{min} (Mc/sec)
January.....	237	218	401	315	2.90	5.02	8.00	1.28
February.....	228	220	387	292	2.89	4.89	8.77	1.20
March.....	241	228	388	294	2.80	4.81	8.51	1.26
April.....	248	233	384	293	2.63	4.74	7.94	1.08
May.....	250	233	380	305	2.44	4.62	6.65	1.00
June.....	226	216	356	292	2.39	4.59	6.14	0.97
July.....	227	214	365	307	2.49	4.63	6.11	1.07
August.....	229	217	378	297	2.60	4.77	7.08	1.05
September....	233	220	389	303	2.67	4.73	7.81	1.28
October.....	236	222	388	302	2.74	4.66	8.49	1.29
November....	235	222	401	314	2.75	4.72	8.52	1.19
December....	233	219	405	320	2.81	4.75	8.26	1.06
Means.....	235	222	385	303	2.68	4.74	7.69	1.14

the magnetic elements, considering all days from July 26, 1941 to June 30, 1942, are: declination, $29^{\circ} 52.9$ east; horizontal intensity, 12576γ ; vertical intensity, 55347γ ; inclination, $77^{\circ} 11.9$ north. The resulting preliminary rates for the annual changes, utilizing average values of the magnetic elements for epoch 1933.5 as supplied by the United States Coast and Geodetic Survey, are: declination, 3.8 west; horizontal intensity, 0γ ; vertical intensity, -22γ ; inclination, -0.3 .

The ionospheric installation—similar to that at the Watheroo and Huancayo observatories—was completed in June 1941. Field-intensity recorders were installed early in July. Since then complete exploration of the ionosphere through automatic continuous photographic recording has been made. The data comprise direct measurements, or deductions from such measurements, of a group of sixteen quantities descriptive of the time-space distribution of ionospheric ionization vertically above the station. The considerable quantity of homogeneous data resulting from the year's operation will require several years for complete analysis, but several important contributions have already been made on the basis of preliminary work. The theoretical postulations of Appleton and Builder (*Proc. Phys. Soc.*, vol. 45, pp. 208–220, 1933) concerning longitudinal type propagation of electromagnetic waves through the ionosphere in the presence of the Earth's magnetic field were confirmed empirically. Ionospheric trends and variations obtained at College were found to be in reasonably good agreement with those expected from extrapolation of observations at stations in the temperate zones. Comparison of theoretical with experimental values of maximum usable frequency added evidence in support of Newbern Smith's method (*Proc. Inst. Radio Eng.*, vol. 27, pp. 332–347, 1939) of deduction, when corrected for ionospheric curvature. A technique was developed for applying these methods to large quantities of data in order that mean values may be converted directly.

Other geophysical investigations at College included both visual and photographic auroral observations during hours of darkness from

October 1941 through April 1942. Estimates of auroral indices based on brilliance, activity, and extent of the displays, as well as details regarding their form and location, were obtained from visual observations at half-hour intervals. The photographic program was confined for the most part to photographs of the region around the zenith obtained at 2.5-minute intervals on 16-mm film by an automatic camera developed at the Department, and built around a Paillard-Bolex moving-picture camera. Preliminary analysis of the visual records indicates a pronounced daily variation in auroral activity with a maximum centering around $02^{\text{h}} 00^{\text{m}}$ local time. Studies of the occurrence of auroras with concomitant magnetic and ionospheric phenomena show that both magnetic activity and abnormal sporadic *E*-region ionization are closely correlated with auroral activity. The correlation was particularly evident when auroras in the zenith alone were considered.

Berkner was in charge of the Observatory through July 1941, when he transferred the Observatory to Bramhall as Physicist-in-Charge and returned to Washington to enter active duty in the Navy as Lieutenant-Commander, September 1, 1941. The other members of the staff were Chief Assistant Seaton, Observer E. Wolff, Assistant Observers Ohlsen (to September 19, 1941, and from January 15, 1942), St. Amand (to May 16, 1942), and Caulk (to September 15, 1941), and Guards Atkinson and Heinrich for part time. The successful prosecution of the extensive program and the prompt compilations of data and reports reflect the competence and energy of the staff.

COOPERATION WITH OTHER OBSERVATORIES

Cheltenham Magnetic Observatory, United States. The cooperative program with the Cheltenham Magnetic Observatory of the United States Coast and Geodetic Survey was continued. CIW instruments on loan to the Observatory were used to control standards in the horizontal and vertical components of geomagnetic intensity. Continuous cosmic-

ray records were made with the CIW model C precision meter. Necessary observations for standardization and control of constants for CIW instruments before and after assignments to the field were made. The interest and help of the Washington staff of the Division of Geomagnetism and Seismology of the Survey and of Observer-in-Charge A. K. Ludy and assistants at the Observatory made for marked efficiency in the cooperative work.

Apia Observatory, Western Samoa. The Department continued cooperation with the Apia Observatory, through its Acting Director, H. B. Sapsford, and staff, in geomagnetic and atmospheric-electric programs. This Observatory also undertakes observations in other fields of geophysics, including meteorology and seismology.

CIW magnetometer 9 and CIW Schulze earth-inductor 2 were used for absolute observations of declination, horizontal intensity, and inclination. Eschenhagen variometers and a Godhavn balance were used to obtain continuous photographic records of declination, horizontal intensity, and vertical intensity. The scale-value of the Godhavn balance proved satisfactorily constant during the report-year. The scale-value as determined with a Helmholtz coil was 1.317 per millimeter and by the oscillation method outlined by la Cour 1.337 per millimeter.

K -indices were determined for the year 1940. K -indices were scaled for the month of January 1938, using 300 gammas (0.003 CGS unit) for the lower limit of the range for a K -index of 9. The frequency-distribution of the various K -indices when compared with that at Cheltenham and Honolulu was satisfactory. Seasonal variation curves in S_q for international quiet days during the summer and winter solstices and the equinoxes were prepared for sunspot-maximum. The amount of the diurnal variation due to lunar effect was determined, and its range was of the order of 3 to 6 gammas.

Atmospheric potential-gradient was measured with a Benndorf electrometer. The leak-free potentiometric method of Gish and Sherman was used to determine the reduction-factor of the Land Station, and results

showed that its value was still 1.00. During 1941, 146 days of zero-character were recorded, with a mean value of 127 volts per meter. The monthly number of zero-days and average potential-gradients are shown in table 14. The annual average hourly values in volts per meter based on the monthly means are as follows: 95, 95, 94, 98, 100, 109, 151, 223, 229, 169, 133, 120, 110, 103, 102, 101, 101, 101, 120, 167, 170, 136, 112, and 100.

The Land Station was closed on December 31, 1941, and the series of atmospheric potential-gradient measurements conducted in cooperation with the Department since 1921 was thus brought to an end. At the close of the first World War the New Zealand government assumed the operation of the Observatory but was unable to provide for the expense of the atmospheric-electric observations. In order to maintain the continuity of the work, the Department entered into a cooperative agreement first with the New Zealand Department of External Affairs and later with the New Zealand Department of Scientific and Industrial Research, to which the financial and technical control of the Observatory was transferred in 1929.

Tucson Magnetic Observatory, United States. Complete and continuous registrations of atmospheric potential-gradient, of positive and negative air-conductivities, and of earth-currents were made at the Tucson Magnetic Observatory of the United States Coast and Geodetic Survey. Observer-in-Charge J. H. Nelson and assistants continued most efficiently this program made possible by the cooperation of the Coast and Geodetic Survey, the Bell Telephone Laboratories, and the Department. Table 15 summarizes the monthly and annual values of the atmospheric-electric elements, as computed by Mrs. G. Dewey, part-time assistant of the Department at Tucson. At Washington, Sherman continued the preparation of the data for publication.

Hermanus Magnetic Observatory, South Africa. CIW magnetometer 17 with earth-inductor attachment continued in use at the Hermanus Magnetic Observatory. The Department cooperates here with the Trigonometrical

TABLE 14

POTENTIAL-GRADIENT AND METEOROLOGICAL SUMMARY, APIA OBSERVATORY, 1941

MONTH	POTENTIAL-GRADIENT		METEOROLOGICAL ELEMENTS					
	No. zero-days	Value (v/m)	Pressure (mb)	Temp. (°F)	Rainfall (in.)	Rel. hum. 9 A.M. (per cent)	Sunshine (hrs.)	Wind velocity (miles/hr.)
January.....	10	120*	1008.3	81	6.76	77	228.2	4.8
February.....	4	136	1005.4	82	20.20	82	154.3	7.2
March.....	6	128	1008.7	81	12.56	78	246.3	6.7
April.....	11	118	1009.9	82	4.43	79	241.3	7.8
May.....	15	116	1010.9	81	1.62	78	218.1	7.2
June.....	18	132†	1011.4	80	2.29	77	240.0	6.8
July.....	13	129	1012.1	78	6.07	76	211.3	9.7
August.....	18	122	1011.1	79	6.95	79	247.9	8.6
September.....	11	123	1011.4	79	2.35	77	234.8	10.6
October.....	18	118	1010.2	79	4.25	71	248.7	7.8
November.....	16	146	1008.7	80	6.93	75	248.0	10.4
December.....	6	134	1008.4	81	6.07	79	232.2	7.1
Totals and means.....	146	127	1009.7	80.2	80.48	77	2751.1	7.9

* Based on mean of 9 zero days.

† Based on mean of 16 zero days.

TABLE 15

PRELIMINARY MONTHLY MEAN VALUES OF ATMOSPHERIC-ELECTRIC ELEMENTS,
TUCSON MAGNETIC OBSERVATORY, 1941

MONTH	No. SELECTED DAYS	POTENTIAL-GRADIENT		AIR-CONDUCTIVITY, UNIT 10^{-4} ESU				
		Reduction-factor	Value (v/m)	All complete days	λ_+	λ_-	$(\lambda_+ + \lambda_-)$	(λ_+ / λ_-)
January.....	17	....	72.2	31	2.01	1.77	3.78	1.14
February.....	18	....	66.3	26	2.03	1.89	3.92	1.07
March.....	18	1.33	58.0	31	2.00	1.82	3.82	1.10
April.....	23	....	48.5	28	2.19	2.09	4.28	1.05
May.....	22	....	48.2	31	2.29	2.22	4.51	1.03
June.....	26	1.28	51.2	28	2.58	2.46	5.04	1.05
July.....	16	....	52.6	28	2.22	2.01	4.23	1.10
August.....	16	....	55.6	29	2.21	2.00	4.21	1.10
September.....	20	....	53.6	24	2.70	2.45	5.15	1.10
October.....	25	1.22	49.7	26	2.70	2.46	5.16	1.10
November.....	26	....	57.6	30	2.27	2.10	4.37	1.08
December.....	24	....	71.0	26	2.00	1.80	3.80	1.11
Totals and means..	251	1.28	57.0	338	2.27	2.09	4.36	1.09

Survey of the Union of South Africa, of which Dr. A. Ogg is Magnetic Adviser. Contact was maintained through Dr. Ogg with the Elizabethville Observatory in Belgian Congo.

Godhavn Observatory, Greenland. Because of the war, cooperation was extended to the Godhavn Observatory by providing maintenance supplies and instrumental replacements, in addition to carrying on the cosmic-ray program already under way there through collaboration with the Cosmic-Ray Committee of the Institution. Thus it has been possible to continue the whole valuable geophysical program at this important station, which otherwise would have been interrupted by the impossibility of receiving supplies from Denmark.

Christchurch Observatory, New Zealand. The collaboration in cosmic-ray recordings and compilations at the Amberley station of the Christchurch Observatory in New Zealand was maintained. Supplies were furnished as necessary.

Royal Alfred Observatory, Mauritius. The loan of CIW marine-inductor 4 was continued for the control of the vertical-intensity records.

Teoloyucan Observatory, Mexico. Dr. J. Gallo, Director of the National Observatory of Mexico in Teoloyucan, continued the cosmic-ray recordings there. Necessary supplies for maintenance of the program were prepared and forwarded.

United States Antarctic Expedition (1940-1941). Physicist Roy G. Fitzsimmons, of the United States Department of the Interior, completed, as guest-investigator at the Department of Terrestrial Magnetism from July 1941 through June 1942, the compilations and discussion of the magnetic data obtained at the Little America Observatory and in the field during the United States Antarctic Expedition of 1940-1941. The manuscript is now in the hands of the Department of the Interior for publication. The final average magnetic elements at Little America III, West Base (not identical with the observatory-locations of the Byrd Expeditions of 1929-1930 and 1934-1935) were for the epoch 1940.7 (April 1940 to January 1941): declination,

104° 57'5 east; horizontal intensity, 0.10050 CGS unit; inclination, 81° 20' south (these values supersede preliminary values given in Year Book No. 40, p. 109). Unfortunately there appears to be some local disturbance in the region about Little America, at least in declination. The mean epochs and values obtained by the two earlier expeditions are: Little America I, declination (1930.0) 106° 49'4 east, horizontal intensity (1929.7) 0.09042 CGS unit, inclination (1929.7) 82° 17'9 south; Little America II, declination (1934.6) 106° 33'2 east, horizontal intensity (1934.6) 0.09444 CGS unit, inclination (1934.6) 81° 53'6 south. The resulting rates of annual changes, reckoning east declination, horizontal intensity, and north inclination as positive, are: declination, 1930.0 to 1934.6, -3'5, and 1934.6 to 1940.7, -15'7 (?); horizontal intensity, 1929.7 to 1934.6, +90 gammas, and 1934.6 to 1940.7, +99 gammas; inclination, 1929.7 to 1934.6, +5'0, and 1934.6 to 1940.7, +5'5.

Assistant Physicist Murray A. Wiener, of the United States Department of the Interior, also of the Expedition, as guest-investigator at the Department of Terrestrial Magnetism from July 3 to December 9, 1941 completed the compilation and discussion of the auroral observations made in 1940 (see Year Book No. 40, p. 110). The manuscript is now also awaiting publication by the Department of the Interior.

The cosmic-ray data obtained from cosmic-ray meters loaned by the Department of Terrestrial Magnetism were compiled and discussed by Korff (see Year Book No. 41, pp. 97-98).

The autumn general meeting of the American Philosophical Society (November 21 and 22, 1941), at Philadelphia, heard reports on the scientific results of the Expedition in a symposium on the "Interest of the United States in Polar Lands." The program of eleven papers included one by Fitzsimmons giving a preliminary report on the magnetic and seismic program, and one by Korff giving a report on the cosmic-ray results.

PUBLICATIONS ON THE "CARNEGIE" DATA

The series of volumes under the general title "Scientific Results of Cruise VII of the *Carnegie* during 1928-1929, under command of Captain J. P. Ault" is now in course of publication. Three quarto volumes on biology will be distributed in July and September 1942. These are: "Biology—I: The copepods of the plankton gathered during the last cruise of the *Carnegie*" (237 pages), by Charles B. Wilson; "Biology—II: The oceanic Tintinnina of the plankton gathered during the last cruise of the *Carnegie*" (163 pages), by Arthur Shackleton Campbell; and (by offset printing) "Biology—III: Studies in the morphology, taxonomy, and ecology of the Peridinales" (129 pages), by Herbert W. Graham.

The next manuscripts in the series, master-copy now in preparation for direct offset printing, are: "Meteorology—I: Meteorological results of the last cruise of the *Carnegie*," by Woodrow C. Jacobs and Katherine B. Clarke-Hafstad; "Meteorology—II: Upper wind observations and results obtained on the last cruise of the *Carnegie*," by Andrew Thomson; "Physical

Oceanography—I: Results within physical oceanography of the last cruise of the *Carnegie*," by Harald U. Sverdrup; and "Physical Oceanography—II: Marine bottom samples collected in the Pacific Ocean on the last cruise of the *Carnegie*," by Roger Randall Revelle.

The decision to use the offset method of printing for the volumes other than Biology I and Biology II will make for economy of publication. This method will also permit earlier issue of the remaining memoirs of the series, publication of which, because of the other urgent demands on the limited personnel of the Department, has had unfortunately to be so long delayed. This delay has been mitigated to some extent by the fact that the original manuscripts for the various reports, and extracts therefrom, have been made available from time to time for use and consultation by other investigators engaged in oceanographic research. Digests and summaries of the memoirs have also been published, as indicated in the bibliographies of publications listed in previous annual reports of the Department.

INSTRUMENT-SHOP

The work of the Instrument-Shop during the report-year totaled approximately 30,800 man-hours, of which 9300 were devoted to the construction of the cyclotron. Approximately 15,300 man-hours were for war purposes, and 6200 for construction of new equipment and experimental apparatus, repairs and improvements to instruments and apparatus, buildings and grounds, and miscellaneous items. The total included some 2600 hours overtime. Steiner continued in charge, with the skilled assistance of Lorz, Haase, Ksanda, Fogel, A. Smith (retired), Balsam, Huff (to July 11, 1941), P. A. Johnson, Buy-

nitzky, Caherty, Thomas (from July 28, 1941), Niemeyer, Roes (to July 31, 1941), Schloer (from April 1, 1942), A. M. Schmidt (to December 31, 1941), F. R. Nichols (to September 10, 1941, and from June 15, 1942), and Garves (February 25 to May 31, 1942). Building Superintendent Smallwood also assisted in the shop and looked after the burden, increased greatly by war operations, of maintenance of buildings and site, with the effective assistance of Malvin and Quade.

The main items of design and construction were: three Gish-Hess ionization-chambers and one electrometer-housing at-

tachment for use with these chambers; automatic auroral camera for use at College, Alaska; 24 new cams for the ionospheric apparatus at College Observatory; two automatic voltage-controllers, one each for the Huancayo and Watheroo observatories; and some improvements in the self-justifying typewriter. Under maintenance may be mentioned numerous replacement-parts for ionospheric apparatus

at observatories, overhauling of two la Cour recorder-clocks for the Godhavn Observatory, and repairs and adjustments to magnetometer-inductors 26 and 28 and earth-inductors 48 and 171.

Because of the heavy demands made by war work, a one-story addition to the shop with 1800 square feet of floor space was completed.

MISCELLANEOUS ACTIVITIES

Some lectures, addresses, and contributions to meetings and physics colloquia, not already mentioned or listed in the bibliography accompanying this report, may be noted as follows: Eleventh Arthur Lecture, Smithsonian Institution, February 26, 1942, "The Sun and the Earth's magnetic field," by Fleming. American Geophysical Union at its annual meeting, April 4, 1942: "Researches in terrestrial magnetism and electricity at the Department of Terrestrial Magnetism, Carnegie Institution of Washington, for year April 1941 to March 1942," by Fleming; "Abrupt daily changes in condensation-nuclei," by Jones and Ledig; "Geomagnetic bays, their frequencies and current-systems," by H. B. Silsbee and E. H. Vestine; "Atmospheric-electric results from simultaneous observations over the ocean and at Watheroo, Western Australia," by Wait. American Institute of Electrical Engineers, University of Maryland Branch, December 10, 1941, "Scientific activities at the Huancayo Magnetic Observatory of the Department of Terrestrial Magnetism, Carnegie Institution of Washington," by Wells. Engineers Club of Baltimore, Maryland, November 26, 1941, "Tagged atoms," by Cowie. National Capital Amateur Astronomers Association, March 7, 1942, "Magnetic effects of the Sun," by McNish. Navy Yard Colloquium, Washington, April 1, 1942, "Fluctuations

in the Earth's magnetism," by Vestine. Physics Colloquium of Washington: December 10, 1941, "Astronomical theory of the ice-caps," and April 1, 1942, "The rotation of the stars," by Gamow. Philosophical Society of Washington, December 6, 1941, "Great geomagnetic storms of the present sunspot-cycle," by McNish. Radio broadcast at College, Alaska (KFAR), December 30, 1941, "Northern lights," by Bramhall, Rainey, and Seaton. McNish prepared for publication in "The progress of science" an article on "Geomagnetism and geoelectricity."

Members of staff took part in scientific meetings and organizations as officers and members and on special committees. Naturally the present emergency curtails such activities, but they are therefore the more important in that maintenance of scientific life, progress, and instruction is also of great importance to the war effort. So far as conditions have permitted, contacts were kept with geophysicists of the United Nations to insure preservation of the framework of those organizations, such as the International Union of Geodesy and Geophysics, which must be depended upon for international scientific cooperation on the return of peace. Members of our staff have served the American Geophysical Union—the organization representing international relations for the United States through the

National Research Council—in various capacities.

Library. The falling off in the receipt of publications from Europe reported last year was further accentuated by the extension of the war to countries which had not been directly engaged in hostilities prior to December 1941. Despite this, accessions totaled 456, as compared with 442 for the last report-year, bringing the total number of accessioned books and pamphlets to 26,659. As in former years, all articles in current periodicals bearing on subjects under investigation by the Department were catalogued.

Librarian Harradon continued as co-editor of the *Journal of Terrestrial Magnetism and Atmospheric Electricity*, dealing especially with the foreign contributions, preparation of notes, reviews of books and reports, and annotated lists of recent publications on geomagnetism, geoelectricity, and allied subjects. His list of published papers by members of the Department to December 31, 1941 showed a total of 2162. Reprints of these papers were regularly distributed to interested institutions and individuals. During the latter part of the report-year, Harradon spent some time in study of the early works on terrestrial magnetism reproduced by G. Hellmann in his *Rara magnetica*, with a view to the possible publication of translations or modernized versions of some of these documents as a contribution to the history of geomagnetism.

Dove continued as Secretary to the Director and had charge of the general files of the Department and the storage and distribution of reprints. He typed a large number of reports and manuscripts, and prepared for binding the "Contributions" from the Department for 1941.

Harradon continued as Secretary of the Section of Meteorology of the American Geophysical Union and as Chairman of the

Committee on Statutes and By-Laws of the Union. A biographical sketch of the late Dr. Louis A. Bauer, first Director of the Department of Terrestrial Magnetism, was prepared for the *Dictionary of American biography*.

As in the past, the facilities of the library were made available to research workers and students from educational institutions and government bureaus. More than in any previous year, the library has been used by specialists, particularly by those engaged on problems concerned with the war. Information on geomagnetism and allied subjects was freely furnished in response to a large number of letters emanating from diverse sources. The practice of interlibrary loans was continued, and reciprocal and cordial relations were maintained with other libraries, particularly with the Library of Congress.

Office administration. The war work undertaken for the government under contracts with the Office of Scientific Research and Development and the Navy Department has required most of the regular time and a great deal of overtime in correspondence, placing of orders, accounting, and matters concerned with the activities of over 200 added temporary employees. Air-raid instructions were prepared by M. B. Smith, Steiner, Smallwood, and Scott. Much time was required in connection with war-work procedures, contracts, requests for priorities, and transfers of personnel. The procedures for maintaining the usual departmental activities, both in Washington and at the three observatories, were complicated also by the emergency conditions and required much more time than ordinarily is the case.

The many details involved in the practically fivefold expansion of administration and personnel were most efficiently handled by M. B. Smith, administrative as-

sistant, and the members of the regular and temporary clerical staff.

Capello, secretary and property-clerk, had charge of shipments and inventory, maintained detailed monthly statements of time and costs of work in the shop, and prepared manuscripts. The drawings, charts, and illustrations for publications

and reports were prepared by Hendrix. He and J. W. Green also handled the photographic work. The records received from the observatories and field were arranged and filed by Miss Balsam, who with Capello kept current the cataloguing of photographic films and index-albums of prints.

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SPECIAL PROJECTS: TERRESTRIAL SCIENCES

COMMITTEE ON COORDINATION OF COSMIC-RAY INVESTIGATIONS. *Progress report for the period July 1941 to June 1942.* (For previous reports ¹ see Year Books Nos. 32-40.)

With the entry of the United States into World War II, activities in cosmic-ray research have been necessarily reduced because of (a) diversion of personnel to war-research problems, (b) impossibility of continuing relations with workers and observatories other than those of the United Nations, and (c) curtailment of laboratory facilities and of equipment and transportation for field-work. Good progress was nevertheless made during the year ended June 30, 1942, as is evidenced by the appended reports of investigators with whom the Committee has been privileged to cooperate through the support of the Carnegie Institution of Washington and the Carnegie Corporation.

There is not the slightest doubt among physicists that the generous and continued support accorded the program of cosmic-ray research during the past decade has added greatly to knowledge and has encouraged "in the broadest and most liberal manner investigation, research, and discovery." The field of cosmic-ray research presents appeal and fascination similar to those found in the outstanding astronomical studies carried on at the Mount Wilson Observatory and so generously supported without undue emphasis upon possible "practical" applications. The cosmic-ray program has forwarded discoveries of the positron, of the mesotron, and of pair-production as a form of energy-production into matter, and information on electrodynamics of the interaction of high-energy electrons, gamma rays, mesotrons, protons,

and alpha particles with atomic nuclei. But the further support of the program should be based on what is not known about cosmic rays rather than on what is known about them. Among outstanding questions in this field are: (1) the source of cosmic radiation; (2) the nature of the primary radiation; (3) the method of production of mesotrons; (4) the nature of the mesotron; and (5) the interaction of matter with extremely high-energy particles.

In a memorandum on "The purposes of cosmic-ray investigation," prepared in January 1942 at the request of the President of the Carnegie Corporation, Dr. S. A. Korff comments on certain aspects of this field. Extracts from that memorandum follow:

"The origin of cosmic rays is at the present time a mystery. It is evidently tied up with the larger aspects of the universe, and it will almost certainly be some time before we understand it fully. On the other hand this in itself provides an intriguing spur to the initiative of investigators. Since the cosmic rays are so abundant and so powerful and since they appear to come from all directions in space regardless of whether or not these regions are occupied by matter, it seems quite possible that the cosmic rays will eventually help to throw some light on the now completely unanswerable questions such as how long has the universe been here, how long may it be expected to continue, how is it supplied with energy, and how much of this energy is left.

"In the realm of high-energy physics cosmic rays provide the only means for research at energies greater than those produced by cyclotrons. The present 225-ton cyclotrons generate energies in the neighborhood of 30 million

¹ For statement on formation, purposes, and policies of the Committee see Year Book No. 38 (1938-1939), pp. 335-349.

electron-volts. The one under construction in California is expected to produce one hundred million electron-volts and possibly more—an energy which should be just enough to generate mesotrons in the laboratory. Until this large cyclotron is completed, cosmic rays will provide the only means for studying these particles; even after it is completed the cosmic rays will provide the only means for studying any but the very slowest mesotrons. The cyclotron now under construction represents doubtless the practical limit which will not be exceeded for many years to come. The whole energy-range beyond this limit is accessible only through cosmic rays.

“Cyclotrons have been of the utmost importance in developing a new field of physics. They were able to produce radiation with the same energy as that with which the nuclei of atoms are held together. In other words, energies produced by the cyclotron and nuclear-binding energies are comparable. The particles accelerated by cyclotrons can penetrate therefore into nuclei and produce transmutations and other nuclear changes. A variety of new elements, many of them of the utmost value in medicine and others usable as tracers in complex biological, chemical, and physiological reactions have been thus produced. The next big field to be explored in physics is that in which the bombarding energies are much greater than the binding energies of the nuclei. The only tool of research in this field is cosmic-ray investigation. Large factors are available in the energies which may be observed These energies are sufficient to disrupt atoms completely, and to permit study of the forces and laws which are at work in their interiors At the present time we can produce million-volt x-rays, and use them for medical treatments. To know what the effect of a billion-volt x-ray will be, we must turn to cosmic rays, which can and do produce such rays and have already revealed some of the properties possessed by them. In this field cosmic rays . . . promise to reveal much about the structure of matter.

“In the possibly ‘practical’ realm, cosmic rays are already beginning to be an important

adjunct in meteorology. Since the cosmic rays come from outer space and are absorbed in the atmosphere through which they pass the intensity at sea-level depends on the amount of air above the instrument, and hence on the atmospheric pressure. The cosmic-ray mesotrons also experience a type of absorption due to ‘decay,’ since they are unstable and spontaneously disintegrate. This decay depends on time and hence on the length of the path over which they pass. Hence the cosmic-ray intensity depends not only on the amount of the atmosphere but also on its distribution, since if the air is warmer, the total atmosphere will expand and the mesotrons which are almost all produced near the top of the atmosphere will decay more because of having to travel further. Consequently a study of cosmic rays gives the meteorologist a picture of what may be happening at altitudes even higher than those accessible to sounding balloons.

“. . . It is well known that disturbances on the sun’s surface produce magnetic storms and concomitant radio fade-outs and dislocations in wire telegraphy and telephony These same storms also affect the intensity of the cosmic rays, especially since the cosmic rays depend on the earth’s magnetic field. The cosmic rays will provide therefore an additional technique for studying the earth’s magnetic field and the changes in it which result from magnetic storms”

Statements of progress from investigators and organizations with whom the Committee has cooperated actively are appended to this report. The study on motion of cosmic-ray particles in the geomagnetic field by Professor M. S. Vallarta at Massachusetts Institute of Technology remains at a virtual standstill because of delay in completion of the differential analyzer and of limitations imposed by the war. The following paragraphs briefly summarize results and progress during the year ended June 30, 1942.

Investigations. Despite the demands of the emergency and consequent depletion

of personnel, Professor A. H. Compton succeeded in maintaining an effective group for the studies of cosmic rays at the University of Chicago. Of special interest were the results of the mountain experiments showing the production of mesotrons by photons and protons, and of the study of the production of mesotrons near the top of the atmosphere by incoming protons. Apparently there was demonstrated for the first time, in the production of mesotrons by photons traversing matter, the interaction of electrical and nuclear forces.

S. E. Forbush, on leave of absence during the entire year on a war-research assignment, found time for general supervision, at the Department of Terrestrial Magnetism, of the compilations and details of maintenance of the cosmic-ray meters at the Cheltenham, Huancayo, Teoloyucan, Christchurch, and Godhavn observatories. Communication with Greenland became more difficult, but, through the courtesy of the Consul-General of Denmark at New York, the American-Danish Greenland Commission, and the United States Coast Guard, the necessary supplies, batteries, and replacements for operation and maintenance were forwarded from the Department of Terrestrial Magnetism.

Miss Isabelle Lange continued the reduction and analysis of the photographic records from observatories despite the necessity of giving a considerable part of her time to computations concerned with war research. The cosmic-ray variations associated with the magnetic storm of March 1, 1942 afford a good example of the need of continued photographic registrations at widely separated stations.

Professor Victor F. Hess and associates at Fordham University corroborated the view that the so-called temperature-effect

of cosmic rays is primarily an effect of atmospheric mass-distribution variations.

At the Bartol Research Foundation, Dr. Thomas H. Johnson, R. P. Shutt, and Sergio de Benedetti made progress on construction of the large high-pressure Wilson cloud-chamber. They completed the analysis of investigations of the composition of the cosmic radiation in the lower atmosphere, and of the processes of interaction of cosmic rays with matter.

Professor S. A. Korff, now at New York University, from analysis of the cosmic-ray data obtained on the United States Antarctic Service Expedition during 1940, found that the fluctuations in cosmic-ray intensity correlated somewhat better with changes in the temperature of the upper atmosphere than with those at sea-level. From experiments at Swarthmore, in Denver, and on the summit of Mount Evans, it was found that a large percentage of neutrons were associated with cosmic-ray showers.

Dr. Robert A. Millikan and his associates and students at the California Institute of Technology made tests at various stations in Mexico and in the United States as to the origin of cosmic-ray energies, and obtained results apparently confirming the hypothesis proposed in the report of last year. The 60-cm high-resolution cloud-chamber for study of the properties of mesotrons was completed. Improvements of cosmic-ray Geiger counters and studies of their mechanisms were made.

Wilson M. Powell and C. E. Nielsen, at the University of California, studied the mass of the mesotron and prepared special equipment for tests to be made at Mount Evans during July and August 1942.

The Committee kept contacts by correspondence and personal conference with many investigators. Grateful acknowledgment is made to the directors and staff-

members of the organizations which continued their contributions and services to the program; these include the Danish Meteorological Institute, the National Astronomical Observatory of Mexico, the New Zealand Department of Scientific and Industrial Research, and the United States Coast and Geodetic Survey.

W. S. ADAMS

J. A. FLEMING, *Chairman*

F. E. WRIGHT

COSMIC-RAY MAGNET

ROBERT B. BRODE

University of California, Berkeley, California

The pressure of war research has prevented further work on the study of mesotrons with the magnet of the Carnegie Institution at the University of California. The magnet has been, however, in nearly continuous use since December 1941 as an essential instrument in a war-research problem. The design of the magnet was fortunately such that it could be used without alteration for this purpose.

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REPORT ON COSMIC-RAY RESEARCH AT THE UNIVERSITY OF CHICAGO

A. H. COMPTON

University of Chicago, Chicago, Illinois

Mountain experiments. During the year 1941-1942 high-altitude experiments on mountains have been performed at stations in Peru and Colorado.

The work by E. O. Wollan and Donald Hughes at the San Cristobal Mine (4750 meters) near Lima, and of Norman Hilberry and Ann Hepburn Hilberry on El Misti (5840 meters) near Arequipa, was

mentioned in last year's report. The persons engaged on these studies were assigned to other urgent work before more than a preliminary analysis of their results could be prepared. This analysis was, however, sufficient to establish the presence of both protons and mesotrons of intermediate energy at these altitudes, and to confirm the very high energy (up to 10^{16} electron-volts) of the primary particles responsible for the "giant showers" that become prominent at the higher altitudes.

On Mount Evans, in 1941, David B. Hall and Marcel Schein studied the energy distribution of mesotrons. Using four counter-telescopes, it was possible to obtain the energy-spectrum of mesotrons with good precision. Using a tray of Geiger-Müller counters, a method was developed for distinguishing between slow mesotrons and electrons. This arrangement made it possible to obtain the spectrum of low-energy mesotrons by pure absorption methods. The spectrum shows, at the elevation of 4340 meters, a pronounced maximum at an energy of about 3×10^8 electron-volts, whereas at sea-level the corresponding maximum occurs at an energy of about 10^9 electron-volts. Such a change in the spectrum of the mesotron had been qualitatively observed in the airplane experiments of Schein, Wollan, and Groetzinger at altitudes of 7500 meters. Theoretical calculations indicate that at least a large part of the slow mesotrons observed at Mount Evans must have been produced at altitudes very close to the place where the apparatus was located.

Victor H. Regener constructed a counter-outfit to study the production of mesotrons. His apparatus consisted of about 150 counter-tubes arranged in trays. Different thicknesses of lead (up to 35 cm) were interposed between the counter-trays. Each individual counter-tube was connected to

a neon-flasher indicating the passage of an ionizing particle through the counter. Working first at Mount Evans, Regener obtained about 100,000 pictures, each showing at least one cosmic-ray particle traversing the counter-set. Several hundred of these pictures show definite evidence of production of mesotrons in the material interposed between the counters.

At altitudes of 4000 meters, 90 per cent of the mesotrons are produced by non-ionizing rays and 10 per cent by ionizing particles. Two kinds of production-process were found: (a) There exists a production of single mesotrons with energies of about 10^8 electron-volts by non-ionizing rays which seem to be photons. No process has previously been observed in which a direct interaction occurs between the electromagnetic and the nuclear field of force. Undoubtedly the nuclear production of a slow mesotron by a photon would represent such a process. A further study of this phenomenon is in preparation. (b) Three per cent of the pictures obtained on Mount Evans show a multiple production of mesotrons. These mesotrons originate mostly from a penetrating neutral radiation. The number of counter-tubes simultaneously discharged indicates an average multiplicity of 6 to 8 mesotrons per producing particle. The mesotrons produced are capable of penetrating a lead thickness of about 20 cm, which corresponds to an average mesotron energy of 3×10^8 electron-volts. This process seems similar in nature to the multiple production of mesotrons by protons found by Schein, Jesse, and Wollan (1941) close to the top of the atmosphere.

Marcel Schein and David B. Hall measured the zenith-angle distribution of mesotrons and electrons. It was found that the slow mesotrons have a different zenith-angle distribution from that of electrons and fast mesotrons. Schein and Hall con-

clude that the soft component does not originate from electrons entering the earth's atmosphere, but from the decay of high-energy mesotrons.

The east-west asymmetry of mesotrons was studied by Schein and Hall on Mount Evans. An excess of 2 per cent from the west was observed. T. H. Johnson has tried to explain the high-altitude asymmetry by a bending of the paths of mesotrons by the earth's magnetic field. The excess of positives present in the spectrum of mesotrons leads to a slight directional asymmetry. The magnitude of the effect found on Mount Evans indicates an average path of these mesotrons between 20 and 30 km. This means that they must have been produced close to the top of the atmosphere.

Variations in the vertical intensity of mesotrons and electrons were compared with barometric changes by Schein and Hall on Mount Evans. For high-energy mesotrons the barometer-effect was found to be of the order 5 per cent per cm of mercury. For slow mesotrons with an energy of 10^8 electron-volts the barometer-effect was as large as 25 per cent. The low-energy mesotrons are also strongly influenced by magnetic disturbances, a phenomenon which was noticed on Mount Evans during the magnetic storm on September 18, 1941.

W. H. Bostick, using a cloud-chamber in the field of a permanent magnet, analyzed the nature of low-energy particles emerging below 2 cm of lead. In addition to the usual shower pictures, a relatively large number of simple mesotron-tracks were obtained. Many of them show definite curvature in a field of 1200 gauss, which means that their energy is below 5×10^8 electron-volts. The relative number of these mesotrons is in accordance with the energy-spectrum of mesotrons found on Mount Evans.

Working at Climax, Colorado, in December, V. H. Regener and R. Lapp studied the production of mesotrons in different materials (paraffin, aluminum, iron, and lead). These experiments show that in light materials the number of mesotrons produced by non-ionizing radiation is much higher than had been expected. In all the materials several mesotrons are produced simultaneously with an average multiplicity of 6 to 8. The cross-section of the production-process was found to be equal to the area of the nucleus hit by the primary particle. The mesotron production-process found in the stratosphere has also a cross-section of nuclear dimensions. It thus seems well established that the production of mesotrons is a nuclear process.

P. Pompeia and E. O. Wollan constructed a counter-outfit to measure the lifetime of the mesotron by a time-delay experiment. The apparatus was similar to that used by Rasetti in Canada. After extensive tests on the ground, the apparatus was set up by Pompeia and Lapp at Echo Lake (Colorado) and later on top of Mount Evans. The experiments are not yet completely analyzed. The preliminary results, however, indicate that several mesotrons were stopped in the absorber without giving out a decay-electron in the time-interval of 1 to 15 microseconds after they were stopped. It would be premature to conclude that the mesotron is directly captured by the nucleus, or that the average lifetime of the mesotron within the solid absorber is much shorter than as measured by Rossi and his collaborators, until further tests are made.

Time-variations of cosmic rays. By courtesy of the Department of Terrestrial Magnetism of the Carnegie Institution, the model-C recording cosmic-ray meters at Christchurch (New Zealand), Huancayo (Peru), Teoloyucan (Mexico), Cheltenham (Maryland, United States), and God-

havn (Greenland) have been kept in operation. Other work has prevented full attention to their analysis. It is hoped, however, that the program of observation, intended to operate through a sunspot-cycle, may be completed.

N. F. Beardsley has assembled a counter-apparatus of large sensitive area for studies of time-variations in cosmic-ray intensity on the ground. This apparatus is now in operation and data are being continuously collected.

Victor H. Regener is constructing five identical counter-outfits which it is planned to station permanently at five different places in the United States. Each of these outfits can be used to measure the changes in vertical intensity of mesotrons with atmospheric pressure and temperature.

Composition of cosmic rays. Marcel Schein and M. Jona have sent counter-outfits carried by balloons into the stratosphere to study the neutral component of cosmic radiation. It was found that within an experimental error of about 2 per cent there is no multiple production of mesotrons by neutral rays present close to the top of the atmosphere. This means that in the stratosphere the number of high-energy neutrons, if any, must be very small. The apparatus used was also capable of registering large showers generated in lead by a high-energy neutral radiation. The absence of these showers strongly indicates that there cannot be any appreciable amount of high-energy γ -radiation entering the earth's atmosphere from the outside. These results confirm the absence of high-energy neutral rays entering the atmosphere.

E. Dershem and M. Schein developed a new type of balloon counter-outfit which can be used for cosmic-ray studies in the stratosphere. In this outfit the coincidence-counts of four different counter-telescopes are collected independently by an elec-

trometer-system. The position of the fiber of the electrometer is recorded on a rotating film. This apparatus, which is capable of registering high-speed counting rates, was sent up once to the stratosphere for measuring the intensity of the soft component. Further flights to high altitudes are in preparation.

Production of secondary radiation. The experiments of Schein, Jesse, and Wollan on the production of mesotrons in the stratosphere have been continued by M. Schein and M. Jona. Multiple production of mesotrons by non-ionizing rays could not be found. It therefore seems that the majority of the mesotrons in the stratosphere are produced by ionizing rays (protons). The angular spread of the mesotrons produced in the stratosphere was investigated and found to be much smaller than on Mount Evans as measured by Regener. This can be explained by the fact that close to the top of the atmosphere the primaries which produce the mesotrons have considerably higher energies (about 10^{10} electron-volts) than the average energy of the mesotron-producing radiation on Mount Evans, which is around 2×10^9 electron-volts.

In a further study, the number of mesotrons stopped between 4 and 8 cm of lead has been measured as a function of altitude. These mesotrons have an energy of about 10^8 electron-volts. The intensity-curve obtained shows the presence of these slow mesotrons in altitudes below 25 km. The curve has a pronounced maximum at a pressure of about 5 cm of mercury. To determine the exact position of this maximum, further high-altitude flights must be made. The presence of slow mesotrons in altitudes below 25 km can be explained on the basis of the assumption made by Carlson and Schein that the mesotrons are produced with an average energy of about

5×10^8 electron-volts and then slowed down by ionization-loss in the air. There is thus no reason to assume, as has sometimes been suggested, that mesotrons occur with a life many times less than that of those now known.

M. Shapiro studied the nature of the particles in cosmic-ray "stars" found in photographic emulsions. His analysis leads to the conclusion that 90 per cent of the tracks in "stars" are protons. The rest is probably due to alpha particles.

Properties of mesotrons. L. Seren measured the number of knock-on electrons in equilibrium with mesotrons. The measurements were carried out in a counter-controlled cloud-chamber. Seren found that the number of collision-electrons originating from mesotrons is in good agreement with theoretical predictions. This is a significant verification of the laws of electrodynamics as applied to particles with extremely high energies.

Personnel. The following members of the Physics Department of the University of Chicago were engaged on this work in July 1941: William P. Jesse, Marcel Schein, Ernest O. Wollan, Donald J. Hughes, Ardis T. Monk, Elmer Dershem, Niel F. Beardsley, and Victor H. Regener. As guests of the laboratory, Paulus Pompeia, Norman Hilberry, and Ann Hepburn Hilberry were active. As graduate students, Winston H. Bostick, Leo Seren, and David B. Hall have made notable contributions. The urgency of other work has required during the year the withdrawal of William P. Jesse, Ernest O. Wollan, Donald J. Hughes, and Ardis T. Monk, as well as of the guests and graduate students just mentioned. The addition of Pierre Auger and A. Rogozinski has greatly helped our situation. The opportunities for important achievement in this field have never seemed more promising.

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STATISTICAL INVESTIGATIONS OF COSMIC-RAY VARIATIONS

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Instruments. Operation of the Carnegie Institution's precision cosmic-ray meters was continued at the following stations: Cheltenham (Maryland, United States) Magnetic Observatory of the United States Coast and Geodetic Survey, meter C-1, A. K. Ludy and John Hershberger in charge; Huancayo (Peru) Magnetic Observatory of the Department of Terrestrial Magnetism, Carnegie Institution of Washington, meter C-2, P. G. Ledig in charge; National Astronomical Observatory of

Mexico at Teoloyucan (D. F., Mexico), meter C-4, Dr. Joaquín Gallo in charge; Amberley Branch of the Christchurch (New Zealand) Magnetic Observatory of the Department of Scientific and Industrial Research, meter C-5, J. W. Beagley in charge; Godhavn (Greenland) Magnetic Observatory of the Danish Meteorological Institute, meter C-6, K. Thiesen and H. P. Barfod in charge.

Reduction of data. Scalings and tabulations of hourly values of cosmic-ray ionization, bursts, and barometric pressure were continued for the records from Cheltenham, Huancayo, and Godhavn, and at Christchurch (by J. W. Beagley). Owing to pressure of war work it has not been possible to maintain the complete reductions current.

Investigations. A further striking example of the magnetic-storm effect on cosmic-ray intensity occurred during the magnetic storm of March 1, 1942. In the 6-hour interval beginning with the sudden commencement of this magnetic storm, the cosmic-ray intensity decreased about 8 per cent simultaneously at Huancayo and at Cheltenham. Sufficient data on magnetic-storm effects on cosmic-ray intensity should soon be available for statistical investigations which may assist in understanding the mechanism involved.

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REPORT ON COSMIC-RAY WORK

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Studies on latitude- and temperature-effect of cosmic rays aboard the "Santa Ana," between New York and Valparaiso.

The registrations of cosmic-ray intensities with a model-C cosmic-ray meter, begun in September 1940, were continued until February 1942. Later registrations were not evaluated since the ship's route was changed and the logs were not available on account of the war. Twelve round trips had been completed in February 1942; the data on the first three trips were incomplete, and therefore only the observations during trips 4 to 12 are being used for publication. A preliminary report was given by Rev. Edward B. Berry, S. J., at the meeting of the American Physical Society in December 1941. (A complete report will be published in the *Journal of Terrestrial Magnetism and Atmospheric Electricity*, September 1942.)

From the correlation of cosmic-ray intensities, corrected for barometric readings, with temperature at sea-level, the temperature-coefficients for all geomagnetic latitudes on the route from New York to Chile were computed. The smallest values of these temperature-coefficients were found to be grouped symmetrically around the geographic equator. The latitude-effect curve, corrected for effect of temperature, was obtained and is generally in agreement with curves in the Pacific, as found by Compton and Turner and by Gill. Certain small deviations can be explained by the longitude-effect of the cosmic radiation.

The influence of the aurora and of the magnetic disturbance of September 18, 1941 was studied with the model-C meter and with counter-telescopes, and a report on these phenomena was published.

Studies on mesotron-disintegration and temperature-effect of cosmic radiation. A dual telescope for continuous registration of the mesotron-component of cosmic radiation, devised and constructed at the Bartol Research Foundation by Dr. W. F. G. Swann in collaboration with Dr. Hess, has been in operation at Fordham Uni-

versity since March 1941. The unit consists of 108 Geiger-Müller counting-tubes in six trays mounted in a vertical counter-train; alternate trays are so connected for coincidence-counting that in reality there are two independent but interposed telescopes of three trays each, with 22 cm of lead between the trays and additional heavy screens for exclusion of side showers. Thus mesotrons coming in from the vertical direction are actuating both telescopes and are recorded by photographing the dials of two special recorders automatically every 2 hours. Reliability of operation is indicated by the constancy, within the natural fluctuations, of the counting-ratio between the upper and the lower telescope. Work with this telescope was begun in collaboration with F. A. Benedetto, S. J., and G. O. Altmann.

The mesotron-intensities obtained were compiled and reduced for 12- and 24-hour periods, and these values, after correction for the barometric effect, were correlated with temperatures at ground and at various levels of the daily atmosphere up to about 16 km, as supplied from the sounding-balloon flights at Lakehurst, New Jersey.

In collaboration with F. A. Benedetto it was shown that there is a continuously decreasing temperature-coefficient as one correlates mesotron-intensities at ground with temperatures at increasingly higher levels. This indicates that air-mass is more fundamental in these investigations, and that when average temperatures are taken by the spatial-average method, the temperatures at the higher levels have undue influence. With the method used by Benedetto and Hess, averages of temperature for various fractions of the atmosphere can be taken which are determined only by the mass of air in each fraction ("mass-temperature"). It was shown that then the temperature-coefficient is almost constant

for all fractions of the daily atmosphere up to four-fifths of the total air-mass. This corroborates the view that the so-called temperature-effect of cosmic rays is primarily an effect of atmospheric mass-distribution variations.

In collaboration with F. A. Benedetto and G. O. Altmann, the changes of mesotron-intensity with change in the average height of the center of gravity of the atmosphere were studied. From the coefficient of displacement derived therefrom, the mean range of life and mean lifetime of the mesotrons at sea-level were calculated.

A complete description of the dual telescope is given in the March 1942 issue of *Physical Review*. In this paper, which gives further results, it is shown that the temperature-coefficient of cosmic radiation varies as dz/dT (change of height of an atmospheric layer with temperature), when increasing fractions of the atmosphere, up to four-fifths of the total atmosphere, are taken. The assumption that mesotrons are produced throughout the atmosphere according to the distribution of the air-mass leads to a mean lifetime of the mesotrons at rest rather smaller than that obtained by other methods. These measurements are being continued by F. A. Benedetto, S. J.

Gish-Hess ionization-meter. In a theoretical study it is shown that, if one computes the ionization produced by gamma rays from radioactive substances in rocks and soil from figures given recently as average values for representative classes of rocks, the expected ionization turns out considerably smaller than that actually observed by placing ionization-vessels over land and over water. Two methods were developed theoretically which make it possible to determine simultaneously the residual ionization, the effect of cosmic radiation, and the effect of gamma rays from

the soil or from rocks (local radiation), and to separate these components of the total ionization.

Comparison of ionizations determined by one of these methods with values computed from given figures of radioactive material in well defined rocks is planned, and the experimental equipment for this work was constructed by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. The author acknowledges the valuable aid of the Director, the Assistant Director, and their associates in the Department during this work.

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STUDIES OF COSMIC RAYS

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During the year ending June 30, 1942, Dr. Johnson and his associates have continued investigations of the composition of the cosmic radiation in the lower atmosphere and of the processes of interaction of cosmic rays with matter. All the experimental studies during this period have

been made with a large Wilson cloud-chamber, fitted with various lead absorbing screens and arrangements of coincidence-counters. With this instrument 42,000 photographs have been taken and analyzed. The analysis of a part of these was reported last year. Although the analysis is now completed, the final conclusions cannot yet be announced.

Out of all the 42,000 photographs taken with the large chamber, only one showed a mesotron reaching the end of its range within the gas in the chamber. From measurements of the curvature and range of this particle, its rest-mass has been estimated as 75 times that of an electron. The particle was negatively charged and gave no indication of having disintegrated. It is interesting to note that the three or four disintegrations of mesotrons which have been observed in cloud-chambers have all been of positive rays. The present photograph represents the third negative particle observed to have stopped in the gas of a Wilson chamber.

Much attention during the past year has been devoted to the construction of a large high-pressure Wilson chamber of novel design. This chamber has been operated with controlled expansions at a pressure of 32,000 pounds per square inch. Good photographs of cosmic rays have been made with the chamber operating at a pressure of 400 pounds per square inch, and visible tracks accompanied by undesirable fog have been observed at 800 pounds per square inch. Now that the problems associated with the control of the expansions are solved, it is hoped that other troubles may soon clear away. This chamber will give a gaseous stopping power equivalent to 1 cm of lead, and it is anticipated that many examples of tracks will be found showing some of the rarer but highly interesting events of cosmic-ray absorption.

Personnel. Because of other requirements on Dr. Johnson's time, the work during this period has fallen almost wholly upon Messrs. R. P. Shutt and Sergio de Benedetti. They have had the assistance, from January 1 to June 30, 1942, of Martin H. Hornstine.

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COSMIC-RAY INVESTIGATIONS

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The cosmic-ray investigations carried out from July 1, 1941 to June 30, 1942, with the aid of funds made available through the Carnegie Institution of Washington, are set forth below.

Cooperation with United States Antarctic Service. The cosmic-ray data obtained on the United States Antarctic Expedition were analyzed. The observational program was divided into several sections. The first of these was the long-term study of the cosmic-ray intensity in Little America through the recordings of two meters during most of the antarctic winter of 1940. The resulting corrected daily means of cosmic-ray intensity were computed. These showed a decrease of intensity during only one of five magnetic storms recorded. This is noteworthy in view of the better correlation shown between magnetic storms and cosmic-ray intensity in temperate latitudes, but is understandable because of the unique character of the geomagnetic field in high latitudes. From

the compilations for an external temperature-coefficient it was found that the fluctuations in the cosmic-ray intensity correlated somewhat better with the changes in the temperature of the upper atmosphere than with those at sea-level. This condition was due to the large inversions of temperature occurring near the surface of the polar ice during the antarctic winter, as a result of which the temperatures at the surface in the Antarctic are not always indicative of the mean conditions in the air-mass overhead. This observation accords well with the view that the penetrating particles in the cosmic-ray radiation are produced at levels in the upper atmosphere, the variations in which levels are determined by the mean air-mass temperatures. Further analysis of these data is still in progress.

On the return trip from Antarctica a meter was operated continuously on board ship. An excellent run through far southern latitudes was obtained, comparable with that obtained on the voyage to Little America the previous year. It was found that the cosmic-ray intensity continued to increase slowly with increasing southerly latitude south of the familiar knee in the curve, but that this increase could be attributed to a decrease in the average external temperature. When an external temperature-coefficient was applied to the data, the curve at all latitudes south of New Zealand was sensibly flat. The fact that it was possible to use an external temperature-coefficient indicates that the air-mass conditions over the ocean in this region are fairly uniform and not characterized by such large temperature-inversions as were found over the ice.

Study of nuclear dissociations produced by cosmic rays. The processes by which cosmic rays produce neutrons and protons through nuclear dissociations were studied at several elevations. The neutrons were

investigated by using a neutron-counter together with cadmium absorbers and a shield of water, which permitted an evaluation of the number of neutrons in the thermal energy-range to be made. The protons produced by the radiation were studied with the aid of a methane counter. These experiments permitted the numbers and rates of production of each to be determined. These rates could then be compared with the other cosmic-ray variables at each altitude. The rates of production of neutrons and protons were found to increase with altitude faster than the total intensity of cosmic radiation and at about the same rate as the soft (electronic) component. Although the total number of neutrons appeared to be considerably greater than the number of protons, when account was taken of the much greater range of the neutrons and of the lower efficiency of the detection of neutrons, it was found that neutrons and protons are produced by the cosmic radiation at roughly the same rate. In this connection it must be recalled that protons and neutrons are present in approximately equal numbers in the nuclei of the light elements studied, that they are bound to these nuclei by energies which though slightly different are of the same orders of magnitude, and further that the energy of the entity producing the disintegration is large as compared with these binding energies. Thus cosmic rays are providing a new tool for the investigation of nuclear structure.

The observations led to the hypothesis of a possible connection between the process of production of neutrons and protons and cosmic-ray showers, namely, that the dissociation producing these particles may be produced by the photons which are present in abundance in the soft component. An experiment was designed to test this hypothesis. The apparatus was

arranged to count those discharges of neutron-counters and of cosmic-ray-shower counters which were coincident in time. The test was made with and without the cadmium shield which absorbs slow neutrons. This experiment gave a positive result indicating that a large percentage of the neutrons were associated with cosmic-ray showers, thus lending support to the suggestion that they are in all probability produced by the photons present in the radiation. These experiments were performed at several elevations, namely, at Swarthmore, in Denver, and at the Cosmic-Ray Laboratory on the summit of Mount Evans.

Personnel. The reduction of the cosmic-ray data obtained in the Antarctic was done by Dana K. Bailey. The records were measured under his supervision by Ernest K. Smith. Correlation-coefficients and dependences on pressure and temperature were computed by Robert A. Taylor. Eric T. Clarke assisted with the nuclear-disintegration experiments made on Mount Evans. It is a pleasure to acknowledge the cooperation of these and other collaborators.

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STUDIES OF COSMIC RAYS

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During the year July 1, 1941 to June 30, 1942, the research time and energies of the whole physics staff at the California Institute of Technology were devoted almost entirely to war problems. Nevertheless, so important cosmic-ray results have seemed to be in process of appearing from the projected program of experiments that some time has been stolen by a few of the workers in that field to push forward in three most significant and promising directions, namely: (1) in the testing in new latitudes by Millikan, Neher, and Pickering of their hypothesis as to the origin of cosmic-ray energies; (2) in the completion by Anderson and his students of their 60-cm high-resolution cloud-chamber for the more accurate study of the properties of mesotrons and the beginning of cloud-track measurements with it; and (3) in the improvement by Neher, Pickering, and Stever of cosmic-ray Geiger counters and studies of the mechanism of such counters.

Tests by Robert A. Millikan, H. Victor Neher, and William H. Pickering, in Mexico and the United States, of the predictions of their hypothesis. (a) Tests in

Mexico: These authors had predicted that since their hypothetical silicon-annihilation rays should have enough energy (13.2 billion electron-volts) to get through the earth's magnetic field at the geomagnetic equator in Peru, though not in India, there should be found at sea-level in the Americas a very long plateau of uniform, vertical cosmic-ray intensities extending north from Peru clear up to about the magnetic latitude of Victoria, Mexico (magnetic latitude, $\Phi=32^{\circ}8$ north). There the strong band due to the annihilation of the oxygen atom (computed energy 7.5 billion electron-volts) should first begin to be able to break vertically through the earth's magnetic field.

To test this quantitative prediction, the observers fitted out a truck as a radio laboratory and in December 1941 drove it as far south in Mexico as they could, namely, to Acapulco. There they made careful measurements on the vertically incoming rays both at sea-level and at all altitudes up to near the top of the atmosphere.

Both of the foregoing types of measurement (those taken at sea-level and those taken by integrating, with the aid of instruments taken up in balloon flights to very great heights, all the incoming cosmic-ray energy at all altitudes) revealed, as predicted, no increase whatever between the latitude of Acapulco ($\Phi=25^{\circ}8$ north) and that of Valles, 375 miles farther north. The upper-air measurements actually showed at Valles a small decrease, which was, however, inside the limits of instrumental uncertainties.

But in going from Valles to Victoria ($\Phi=32^{\circ}8$ north), a distance of but 112 miles, there was found a sudden, unambiguous rise in both the sea-level vertical intensity and the total integrated vertically incoming cosmic-ray energy. These findings were, then, in excellent agreement with the predictions of the theory as to the

approximate latitude at which the cosmic rays due to the annihilation of oxygen atoms should first begin to appear as the observer travels north in the Americas from the magnetic equator.

A further check on the theory was found in the following situation. If there were any sort of continuous distribution of the incoming cosmic rays with incident energy, then, since the earth's magnetic field is stronger in India than in Mexico, the intensity of the vertically incoming rays should be greater in Acapulco, Mexico ($\Phi=25^{\circ}8$ north) than in Peshawar, India ($\Phi=25^{\circ}$ north). But the hypothesis denied the possibility of this result. Five different flights were made in Acapulco to test this point. The best of these flights gave practically the same vertical cosmic-ray intensity as that found in the observations taken in Peshawar in 1940. The mean in Acapulco was slightly lower than in Peshawar, though not enough so to be outside the limits of instrumental uncertainty.

(b) Tests in the United States: Again in driving the truck-laboratory from the latitude of Victoria, Mexico ($\Phi=32^{\circ}8$ north) to that of San Antonio, Texas ($\Phi=38^{\circ}4$ north) and Pasadena, California ($\Phi=40^{\circ}7$ north), where the vertical sea-level intensities were found to be the same, the hypothesis required that at the two last latitudes the annihilation-rays both of oxygen atoms and of nitrogen atoms should be added to the annihilation-rays of silicon atoms, as measured in Peshawar in India in 1940 and in both Acapulco and Valles in December 1941. The observations both of sea-level intensity and of integrated energy revealed the predicted large increase between these latitudes (over 30 per cent).

The observers also made in March 1942 preliminary and less dependable measurements of the changes in integrated energy

in going from Pasadena, California ($\Phi = 40^{\circ}7'$ north) to St. George, Utah ($\Phi = 45^{\circ}$ north). Their single flight at St. George showed an increase of 18 per cent over that at Pasadena. This increase they attribute to the entrance between these latitudes of the carbon-atom-annihilation rays.

In going from St. George to Pocatello, Idaho ($\Phi = 51^{\circ}$ north), a change of 6° in contrast with the change of 4° from Pasadena to St. George, they found in their only measured flight no increase—a result required by their hypothesis, since there are no abundant atoms of atomic weight between that of carbon and that of helium.

(c) Discovery of large variability of helium-annihilation rays: Within the year (in August and September 1941) these same observers made a series of accurate measurements of total incoming cosmic-ray energy as measured by electroscopes, rather than by vertical counters, sent to close to the top of the atmosphere at Bismarck, North Dakota ($\Phi = 56^{\circ}7'$ north), Omaha, Nebraska ($\Phi = 51^{\circ}3'$ north), Oklahoma City, Oklahoma ($\Phi = 45^{\circ}$ north), Fort Worth, Texas ($\Phi = 41^{\circ}6'$ north), and San Antonio, Texas ($\Phi = 38^{\circ}4'$ north). These accurate measurements brought to light the notable fact that whereas the total incoming energy at San Antonio was the same as that measured there in 1935, the helium-annihilation rays coming in at Bismarck, measured within a week of the measurements at San Antonio, showed at the top an increase of at least 30 per cent over measurements of the same sort made there in 1938. The soft rays due to helium are, then, very much more variable than are the hard rays due to the heavier and very much less abundant atoms. Whether this variability in the softest component of the incoming rays is due to changes in the magnetic field of the earth or of the sun or

represents a more fundamental variability in the rate at which helium atoms are being transformed in outer space into cosmic rays is yet to be determined.

Work of Carl D. Anderson, Leon Katz, and R. V. Adams on a high-resolution cloud-chamber for the accurate determination of the properties of mesotrons. The large magnet-cloud-chamber apparatus at the California Institute has been in operation during the year July 1941 to June 1942. In all only about 1000 photographs were taken, as most of the time was spent in improving the operation of the apparatus, principally with regard to decreasing the small distortions of the tracks due to motions of the gas. These motions are the most important factor in limiting the accuracy of the energy-measurements. Several different designs of the moving diaphragm have been tested, the timing of the illumination has been improved, and better temperature-control has been achieved. At present it is possible to measure energies in good tracks up to 20 billion electron-volts with fair precision. A system for measuring the tracks by re-projecting the images and thus eliminating all lens distortion has been completed.

Improvement in cosmic-ray Geiger counters and studies of the mechanism of such counters, by H. Victor Neher, William H. Pickering, and H. G. Stever. As an offshoot of the development of high-altitude Geiger-counter observations, these workers made fundamental studies in the operation of Geiger counters. These led directly to the development of a new type of counter, in which the central wire is provided with glass beads which isolate the counter into sections, and which thereby not only permits coincidence-measurements with a single counter, but illuminates from a new angle the whole theory of counter-action.

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MASS OF THE MESOTRON

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On July 1, 1941, an expedition to the summit of Mount Evans (14,125 feet) was already under way. This work and its development had been made possible through the support of the Rumford Fund for the Study of Radiation of the American Academy of Arts and Sciences, the Penrose Fund of the American Philosophical Society, the Fund for Astrophysical Research, and the John Simon Guggenheim Memorial Foundation. Preliminary reports on six months' examination of over 20,000 photographs of cosmic rays passing through a large Wilson cloud-chamber obtained on that expedition were published in *Physical Review* (see bibliography); a complete paper on the results is in preparation. Many valuable suggestions in interpreting the results were given by Professor J. R. Oppenheimer.

CALIFORNIA INSTITUTE OF TECHNOLOGY, Pasadena, California. *Cooperative researches at the Seismological Laboratory*. (For previous reports see Year Books Nos. 37 to 40.)

One part of the research program at the Seismological Laboratory at Pasadena is concerned with local earthquakes, that is,

As a result of this work, and with the continued financial support of the organizations above mentioned and of the Carnegie Institution of Washington, plans were made to measure the mass of the mesotron with a cloud-chamber and a magnetic field. A new cloud-chamber was made following techniques developed by Professor R. B. Brode and his students at the University of California, and utilizing some apparatus obtained by the Department of Physics of the University. The new cloud-chamber is used with a large pair of Helmholtz coils. These coils are supplied by storage batteries with a large current at the moment of expansion and photography of the cloud-chamber. Statistical treatment of the data obtained through the earlier random photographs at the summit of Mount Evans indicates that a large number of slow mesotrons may be observed whose ionization is measurably denser than that of a high-energy electron.

Dr. Carl E. Nielsen, of the University of California, assisted in this research and in preparation of apparatus, and after the transfer of Dr. Powell to war-research activities, on June 10, 1942, took full charge of the investigation. After tests at Berkeley, which showed that the whole apparatus functioned as expected, he reached the summit of Mount Evans with practically all the equipment, mounted in a trailer.

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those originating in southern California and adjacent territory. The purposes of this part of the program include the de-

termination of the following: the seismicity of southern California and of its different parts; the relations of earthquakes to the faults known in the region; the origin and nature of shocks not originating on the more important faults but within the great crustal blocks; the depths of the origins of shocks; the accelerations, periods, and other elements in local earthquakes, desired by engineers as data for computing strengths of structures to be built in the region; and the nature of the forces causing the mountain making and the earthquakes in this part of the state. Another part of the activity of the Laboratory deals with broader geophysical and tectonic problems, for which the data from both local and distant earthquakes are essential. Among such problems are the thickness and the nature of the earth's so-called crust in the different parts of southern California, the thickness of the crust where deformed by past mountain making, and the quantitative relations of such elements of earthquakes as their magnitudes, intensities, and accelerations.

The largest amount of data obtainable, in the form of precise seismographic records, is none too extensive for the successful prosecution of the researches on the problems mentioned above. For this reason the instruments at the Pasadena laboratory and the seven outlying stations in southern California are kept in continuous operation. After many years' effort, they now write very accurate records and permit time determinations of the phases of earthquakes to a small fraction of a second. The Laboratory's records now, together with those obtained by the University of California in central California, those made by the U. S. Bureau of Reclamation at Lake Mead, and those written by the U. S. Coast and Geodetic Survey at Tucson and on their strong motion instruments at numerous localities in the Southwest,

give a better set of data on every earthquake occurring in the Southwest than has ever been available before. The systematic registration of shocks in this region can continue for a long time to come before the effort and expense will begin to yield decreasing returns both on the practical and on the theoretical side of seismology and geophysics.

A full program of registration has been continued during the year at the Pasadena laboratory and at the seven outlying stations, including Palomar.

Though equipment has been maintained and some improvements have been made at some of the stations, instrument design and construction are in abeyance for the duration of the war. Dr. Benioff and his mechanical staff are engaged on government research and construction, utilizing the shop facilities of the Laboratory.

Mr. Robert E. Rogers accepted a commission in the U. S. Navy and was granted a leave of absence to begin July 15, 1942. Miss Patricia Hawkins begins service as an assistant in the measurement of records on July 1, 1942. Miss Catharine McCollum will take charge of the photographic and related work in the Laboratory on September 2, 1942.

Crustal structure. The earth is made of concentric shells of different types of rock material. The outermost shell, or crust, consists of an upper or granitic layer, which forms the continents, and deeper layers of comparable thickness made of basic igneous rock. The average thickness of the crust is about 35 or 40 km. The detailed nature of this crust has been under vigorous investigation at the Seismological Laboratory during the past year. Answers were desired to such questions as, What is the thickness of the two parts of the crust under southern California, and under mountains? Do mountains have "roots," and what happens when

mountains are formed by telescoping of the crust, with reference to the thickening of the granitic plate or upper part of the crust and with reference to the basaltic or lower part? Do the lower surfaces of these layers bulge downward, each into the heavier layer next below, in order to support the upward bulge of the granitic layer which we recognize on the surface as a mountain range?

The investigation of the foregoing and related questions during the current year has yielded extensive results, partially embodied in three papers already in course of publication and in other manuscripts in preparation. Two of these papers, by Dr. Beno Gutenberg, are "Earthquakes and structure in southern California" and "Seismological evidence for roots of mountains."

Some of the important new conclusions, with the evidence therefor, brought out in these two papers are as follows: The granitic layer in southern California is about 18 km. thick, and the basaltic layers beneath it, forming the lower part of the crust, are about 22 km. thick, giving a total thickness of about 40 km. for the crust in this region. In southern California both the thickness of the granitic layer and the total thickness of the crust are considerably less than the average thickness under Europe, and it appears that the basic layers forming the lower part of the crust are of somewhat different composition from those under Europe. All the earthquakes in southern California apparently originate near the base of the granitic layer, that is, at a depth of about 18 km. Under the Sierra Nevada the total thickness of the crust is considerably greater than in other parts of southern California, being about 60 km., but, surprisingly enough, the granitic layer is no thicker than in surrounding areas. The basaltic layers forming the lower part of the crust have thickened

from about 22 to about 42 km. This thickening of only the lower layers of the crust under the Sierra Nevada is in marked contrast with conditions in the Alps, where the main thickening occurred in the granitic or uppermost layer of the crust. In the Alps the total thickness of the crust is also about 60 km., but the granitic layer was thickened to about 40 km. Outside the Alps, in Yugoslavia, the granitic layer, below about 4 km. of sediments, is about 13 km. thick, and the underlying basaltic layers about 25 km., giving a total of about 42 km. In New Zealand the granitic layer is only about 10 km. thick, and the basaltic layers about 20 km., so that the total crustal thickness is only about 30 km.

It was possible also to obtain some data on the horizontal extent of the Sierran root or thickened part of the crust. It does not extend much east of the east base of the present upfaulted range, and it does not extend westward beneath the San Joaquin Valley. It is best developed under the highest part of the range, and does not extend southward under the Tehachapi Mountains, which are sometimes considered to be the southern part of the range.

In the Alps the mountain making, folding, and faulting occurred after the great granitic batholiths were emplaced; in the Sierra Nevada probably the reverse is true for the great Jurassic mountain making. The question whether this explains why the granitic layer is greatly thickened under the Alps but not under the Sierras should be further investigated.

Some progress has also been made in determining why waves arriving at a given seismographic station arrive "too early" or "too late." These differences in travel time appear to be due to two causes: differences in paths through the deeper layers, which vary in thickness, and differences in the other rocks near the station through

which the sedimentary waves pass in the last part of their paths.

It has also been found that whereas all the larger shocks occur on the more important faults, many of the minor shocks occur on minor faults within the major fault blocks. This probably means that the shearing forces involved in mountain making are in part relieved by slips on the major faults and in part by internal deformation of the major fault blocks into which the region being deformed has been cut by the major faults. If this assumption is correct, this is a very important and fundamental fact in tectonics or structural geology.

In the course of the investigations on the above problems other results of very fundamental nature were obtained. These are being published in a joint paper by Dr. Beno Gutenberg and Dr. Charles F. Richter, entitled "Earthquake magnitude, intensity, energy, and acceleration," to be issued in the July 1942 number of the *Bulletin of the Seismological Society of America*. This paper sets forth the relations of the important elements in earthquakes: the magnitude, which may be said to be measured by the size of the area shaken; the intensity or vigor of the shaking; the total energy released in the earthquake; and the maximum accelerations in the shock. Equations for relating quantitatively all these elements in an earthquake are developed for the first time.

Conspectus of seismologic stations. In the study of past earthquakes it is important to know what seismological stations were in existence at different times. During the year Mr. H. O. Wood completed and published "A chronologic conspectus of seismologic stations," containing data for more than 800 stations which have been in operation for longer or shorter periods in different parts of the world.

Southern California earthquakes. A

number of important earthquakes occurred in southern California during the year. Most of them provided valuable additional data for Gutenberg's study of travel times and structures.

On September 14, 1941, the central Sierra Nevada region was shaken by a group of shocks, the largest of which was of magnitude 6. Many rock slides, some of which were large, were started in the range. Gutenberg determined an epicenter on Owens River in Long Valley. Aftershocks were very numerous; a large one (magnitude 5.5) occurred as late as December 30.

On September 5 a shock of magnitude 5 occurred on or close to the San Andreas Fault in Cuddy Valley. Gutenberg's study shows that earlier shocks in the same region certainly originated north of this one, so that there must be activity north of the visible rift.

On October 22, a shock of magnitude 5, originating on the Inglewood fault zone, caused some damage at Gardena. An offset occurred on a subsurface fault in the near-by Dominguez Hill oil field. The seismological evidence shows that the point of initial rupture in the earthquake was at the usual depth (about 15 to 18 km.), and not under the fracture in question; the displacement on this fracture must be considered as having been triggered by the main earthquake. The secondary earthquake source thus produced seems to have added to the local intensity in the immediately surrounding area.

On November 14 a larger shock (magnitude 5.5) originated farther to the southwest; this shock produced no further effects in the Dominguez field, but caused extensive damage at Torrance and Gardena.

On February 1, 1942, there was a long series of minor shocks (magnitudes up to 4.5) in the Lucerne Valley area north of the San Bernardino Mountains.

On March 5 a shock of magnitude 5 originated still farther east, in the Pinto Mountains. Exact study of a shock so far east might have provided much valuable information on the structures transitional between those of the Coast Ranges and of the Colorado Plateau; but Gutenberg found that the comparatively large distance from all the more sensitive stations, and the generally unfavorable location, renders any conclusions uncertain. The later installation of more sensitive instruments in the Lake Mead area may make it possible to carry out complete investigations on future shocks in this interesting transitional region.

Of the many distant shocks recorded, at least fifteen were of magnitude 7 or over (major earthquakes). The great Atlantic shock of November 25, 1941 approached magnitude 8.5, and thus may have been the largest earthquake since 1922. At Pasadena the surface waves were recorded with amplitudes up to 2.5 mm. (actual displacement of the ground).

Research on sound waves. Research was continued on the propagation of waves in the atmosphere, applying the laws of elastic waves used in seismology and utilizing equipment specially constructed at the Seismological Laboratory for the purpose. A short paper was published by Gutenberg and Benioff on some of the results secured.

During the year the following papers were presented: At the meetings of the Geological and Seismological Societies of America at the California Institute of Technology on April 17-18, 1942: "Earthquakes and structure in southern California," by Beno Gutenberg; "Technique in calculat-

ing epicenters," by Charles F. Richter; "Determination of epicenters and travel times in southern California," by Beno Gutenberg; "Earthquake magnitude, intensity, energy and acceleration," by Beno Gutenberg and Charles F. Richter; "Gouge is not positive fault evidence," by John P. Buwalda. At the April 1942 meeting of the Mathematical Society at Berkeley: "Mathematical questions in seismology," by Charles F. Richter.

Both Dr. Gutenberg and Dr. Richter have devoted a part of their time during the year to defense research and instruction.

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UNIVERSITY OF PITTSBURGH, Pittsburgh, Pennsylvania. *Microcalorimetric studies of the thermal properties of dilute solutions.* (For previous report see Year Book No. 40.)

These studies were started in September 1940 and have been carried on by Dr. William E. Wallace under the direction of

Dr. A. L. Robinson, of the Department of Chemistry of the University of Pittsburgh, and in cooperation with Dr. R. E.

Gibson, of the Geophysical Laboratory of the Carnegie Institution of Washington.

Measurements of the heats of solution and dilution of calcium sulfate dihydrate in sodium chloride solutions have been completed. Results of this investigation were presented before the Physical Section at the American Chemical Society meeting in Memphis, in April 1942.

The heats of dilution of aqueous glycine solutions have been investigated. Results of this study have been prepared for publication.

The heats of dilution of some lanthanum salts have been under investigation. Satisfactory data have been obtained using lan-

thanum chloride and lanthanum sulfate. These results have also been prepared for publication.

The microcalorimeter used in the above studies has undergone alteration of such nature that nonaqueous solvents can now be accommodated. At the present time (June 1942) work is in progress involving measurements of the heats of dilution of sodium chloride in ethylene glycol.

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JOSEPH C. BOYCE, Massachusetts Institute of Technology, Cambridge, Massachusetts. *Research in the spectroscopy of the vacuum ultraviolet*. (For previous reports see Year Books Nos. 38 to 40.)

This research, supported for three years by grants from the Carnegie Corporation of New York to the Carnegie Institution of Washington, continued into its fourth year on an unexpended surplus from previous years. Early in the year covered by this report it became apparent that the demand for trained research workers and for shop facilities would soon put a stop to all research work not directly contributing to preparations for war. It was therefore decided, before the experienced personnel of the project should be scattered, to discontinue the program of photographing additional spectra and to proceed with the reduction of observations on some representative spectra. In this way it would be possible to evaluate the results attained to date in this program and in the parallel Works Progress Administration program for the measurement of the spectra.

The most reliable wave-length standards between $\lambda 2000$ and $\lambda 1300$ are those of Cu II determined by Shenstone (*Philos. Trans.*

Roy. Soc., A, vol. 235, pp. 195-243, 1936) and of Fe II by Green (*Phys. Rev.*, vol. 55, pp. 1209-1217, 1939) and by Edlén (unpublished data in substantial agreement with Green but containing additional lines). These are each based on combinations between spectroscopic terms which can themselves be located from lines in the longer wave-length region of the spectrum. By a happy relation (J. C. Boyce, *Rev. Mod. Phys.*, vol. 13, pp. 1-57, 1941; see especially p. 21) between wave length and wave number, at various wave-length regions, the wave-length accuracy of these standards in the short wave-length region is somewhat greater than that of the longer wave-length lines used in determining the term values. Most of the copper lines arise from high levels in the copper ion, not ordinarily excited in sparks, and require Schüller cathode excitation. Furthermore, there are considerable gaps between standards in each of these systems.

Mrs. Lyman therefore undertook a critical study of all available exposures of cop-

per (spark and Schüller tube excitation), iron (spark excitation), and mixtures (in a pressed-powder electrode) of copper and iron (spark excitation), as well as of sparks of silver and of silver-copper and silver-iron mixtures. Six exposures of copper, two of iron, and five of an iron-copper mixture were selected which had all been measured by means of the Harrison automatic comparator (*Jour. Opt. Soc. Amer.*, vol. 25, pp. 169-178, 1935). On every plate examined, the values for the wave lengths of the lines used were checked as to accuracy in reading the microphotometer films and in the arithmetical averaging of the six individual readings of each line. In most cases only the values of the standards on the plates were examined. On one Fe plate and four Cu plates, all the lines were checked.

Fe and Fe-Cu. Calibration curves using Edlén's Fe standards as true values were drawn for the standards from two Fe plates. The wave lengths of the lines were corrected from the curves. Each of these two plates was remeasured on the automatic comparator. New calibration curves were drawn and the values of the standards read from the curves.

Several Fe calibration curves were obtained from Fe-Cu plates. The corrected values of the Fe standards from all the Fe and Fe-Cu measurements were assembled and averaged, and the final values corresponded so closely to Edlén's values for the standards that his list with the exception of a few lines was adopted as the Fe standard list. Edlén's Fe standards did not uniformly represent the range desired, however, so the plates were examined for additional lines which might be used as standards. Several values for the lines picked out were obtained from the respective correction curves for those plates. The averages of these values were added to the Edlén Fe standard list as possible addi-

tional Fe standards, giving a range of standards from $\lambda 1400$ to $\lambda 2050$. Some of the new standards were Fe II and some Fe III lines.

Cu and Cu-Fe. Since most of Shenstone's calculated Cu lines appeared only in the Schüller tube excitation of Cu and not in the spark spectra of Cu, it was necessary to pick out spark Cu lines which could serve as standards on spark plates. The values of the proposed Cu standards were read on Cu-Fe plates and corrected by means of the Fe calibration curves. The Cu standards were read from Cu plates and calibration curves for the Cu standards drawn. The averages of all the possible values of the Cu standards were obtained (two Cu plates being remeasured and read as additional checks). A list of Cu spark standards was then compiled which covered the range from $\lambda 1300$ to $\lambda 2000$. Some of the lines were Cu II and some Cu III.

Four Cu Schüller tube plates were also read and the measured wave lengths of the standards corrected from calibration curves containing many of Shenstone's calculated Cu lines.

Ag, Ag-Fe, and Ag-Cu. The Fe and Cu standards were then used in an attempt to determine some Ag standards. Gilbert's work on Ag III (*Phys. Rev.*, vol. 47, pp. 847-850, 1935; vol. 48, pp. 338-342, 1935) was used as a comparison with the new measurements. A term array of Ag III based on the new measurements from Ag-Fe plates between $\lambda 1600$ and $\lambda 1700$ and between $\lambda 1800$ and $\lambda 1950$, and on Gilbert's values above $\lambda 2050$ was attempted, but the results were very unsatisfactory and in very poor agreement with Gilbert's values. The Ag-Cu plate gave a poor Cu calibration curve, and since there were many Ag-Cu blends, the attempt to obtain Ag standards was abandoned for the time being.

Table 1 presents the previous and the added wave-length standards in the range from λ_{1309} to λ_{2041} in both copper and iron, arranged in order of wave length. The accuracy of the older data, based on the combination principle, is believed to range from 0.002 to 0.004 Å. The newer data are inherently somewhat less accurate, but an estimate of 0.005 Å as their probable error seems reasonable.

Titanium was selected as an element whose spectra in the vacuum ultraviolet were simple and fairly well understood, but for which the published wave-length measurements (H. N. Russell and R. J. Lang, *Astrophys. Jour.*, vol. 66, pp. 13-42, 1927; H. N. Russell, *ibid.*, vol. 66, pp. 283-328, 1927) were not of high accuracy. Miss Pitkin assembled and checked wave-length data from representative exposures of titanium and of mixtures of titanium with iron and copper. The wave-length standards listed in table 1 were used in the reduction of these measurements, as slight corrections to the data given by the automatic comparator. About 60 lines of Ti III between λ_{1282} and λ_{1948} were fitted into a term array, following Russell and Lang, but permitting a considerably more precise determination of term values. About 10 lines which had not been given by Russell and Lang could now be classified. The multiplet of Ti II in the vicinity λ_{1910} was remeasured, as were a few lines of Ti IV. Publication of these results has been deferred until there is opportunity to extend the measurements to the region of shorter wave lengths.

The precision of these data, as evidenced by the accurate fit into term arrays, as well as by the check with Edlén on the iron measurements, gives evidence as to the reliability of the large amount of data contained in the collection of spectra. When work is resumed after the war, the observational program should be directed to-

ward obtaining spectra from vacuum sparks, to give somewhat higher excitation than has been obtained in the previous observations. This will assist in assigning hitherto unclassified lines to the appropriate stage of ionization and will extend the range of the measurements down to perhaps λ_{500} . At the same time the program for the reduction of observations should be considerably expanded. The collection of films from the Harrison automatic comparator will be very useful, as will many of the W.P.A. readings and averagings from these films. As would be expected of such results obtained by untrained workers, the recent studies have shown that this computational work has varying reliability and must be carefully checked.

An important spectroscopic paper published during the year by B. Edlén and P. Swings is based in part on data obtained in 1937 with the Carnegie spectrograph. These investigators have measured the third spectrum of iron in the region from approximately λ_{500} to λ_{6500} and have carried out a very complete term analysis. The measurements between λ_{2023} and λ_{1382} (some 400 lines) were based exclusively on plates taken by Edlén while he was a guest in this laboratory. The same plates gave 150 additional lines attributed to Fe III in the regions up to λ_{2338} and down to λ_{1017} , regions in which the observations with the Carnegie instrument were overlapped by those with a quartz-prism spectrograph and with a grazing-incidence vacuum spectrograph, respectively.

The analysis of Fe III by Edlén and Swings is the most complete one ever carried out for the third spectrum of a metallic element. Of the 34 theoretically possible terms of the $3d^6$ configuration, 32 have been found. Of the 74 theoretical levels for $3d^54s$, only 10 high-lying levels

TABLE 1

PREVIOUS AND NEW WAVE-LENGTH STANDARDS IN IRON AND COPPER

INT. (ARBI- TRARY SCALE)	SPECTRUM	Fe		Cu		INT. (ARBI- TRARY SCALE)	SPECTRUM	Fe		Cu	
		Edlén	New	Shenstone	New			Edlén	New	Shenstone	New
4	II	.....		1309.463		3	.....			1588.542	
$\frac{1}{2}$	II	.....		1326.394		0	II	.....		1590.164	
$\frac{1}{2}$	II	.....		1329.654		3	.....			1592.967	
3	II	.....		1337.544		2	.....			1599.415	
4	II	.....		1339.463		2	II	.....		1602.387	
0	II	.....		1363.501		5	II	1610.922		.....
4	II	.....		1367.952		5	II	1612.805		.....
1	II	.....		1371.451		3	.....			1621.695	
5	II	.....		1377.477		5	II	1623.090		.....
3	II	.....		1393.126		5	II	1625.520		.....
2	.....	1401.756		.....		4	II	1632.665		.....
1	.....	.....		1403.722		5	II	1633.906		.....
2	II	1405.605		.....		5	II	1637.398		.....
4	II	.....		1407.160		5	.....			1639.945	
4	.....	1413.685		.....		5	II	1640.150		.....
3	.....	.....		1418.779		5	II	1643.576		.....
1	II	1418.851		.....		4	II	1654.476		.....
3	.....	1420.901		.....		5	II	1658.771		.....
4	II	1424.714		.....		5	II	1659.479		.....
3	II	1434.994		.....		5	II	1663.220		.....
2	II	1442.746		.....		2	.....			1665.563	
3	.....	1448.387		.....		4	.....			1669.272	
3	.....	1456.464		.....		5	II	1673.466		.....
3	.....	.....		1460.896		5	II	1674.254		.....
3	.....	1463.196		.....		5	II	1674.715		.....
2	.....	1472.040		.....		4	II	1676.854		.....
4	II	.....		1472.399		6	.....			1682.666	
3	.....	.....		1472.837		1	II	.....		1683.150	
2	.....	1478.112		.....		4	II	1685.952		.....
3	.....	1489.918		.....		5	II	1686.454		.....
2	.....	1498.288		.....		4	II	1686.690		.....
3	.....	.....		1502.082		4	II	1689.832		.....
3	.....	1506.897		.....		4	II	1690.755		.....
2	.....	.....		1509.951		4	II	1691.272		.....
3	.....	1522.685		.....		3	II	1693.935		.....
3	II	.....		1532.124		5	II	1696.794		.....
3	.....	1533.440		.....		4	II	1699.195		.....
6	II	.....		1537.560		4	.....			1704.052	
3	II	1548.694		.....		5	II	1708.621		.....
5	II	.....		1549.202		6	II	1712.998		.....
4	II	.....		1550.644		2	.....			1713.335	
3	II	.....		1551.379		4	II	1716.576		.....
2	II	1551.929		.....		1	II	.....		1717.72	
5	II	1558.538		.....		5	II	1724.853		.....
5	II	1558.691		.....		5	II	1724.962		.....
3	.....	.....		1561.788		5	II	1726.391		.....
0	II	.....		1566.411		3	.....	1731.858		.....
5	II	1566.821		.....		3	.....	.....		1732.976	
5	II	1568.017		.....		4	.....	1740.316		.....
5	II	1569.674		.....		5	.....	.....		1751.216	
5	II	1570.244		.....		4	.....	.....		1754.994	
5	II	1573.826		.....		5	.....	1761.371		.....
5	II	1574.769		.....		3	II	1764.117		.....
5	II	1574.921		.....		1	.....	.....		1766.202	
2	.....	.....		1581.264		5	II	1772.512		.....
1	II	.....		1583.683		2	.....	.....		1780.039	
5	II	1584.949		.....		4	II	1793.367		.....
5	II	1588.288		.....		2	.....	.....		1798.737	

(Continued on following page)

TABLE 1—*Continued*

INT. (ARBI- TRARY SCALE)	SPECTRUM	Fe		Cu		INT. (ARBI- TRARY SCALE)	SPECTRUM	Fe		Cu	
		Edlén	New	Shenstone	New			Edlén	New	Shenstone	New
3				1826.317		4		1957.922			
4	II	1835.872				5		1960.302			
4	II	1846.574				4		1965.294			
4	II	1848.771				2	II			1970.489	
5	II	1860.052				4	III	1976.114			
4				1867.729		6	II			1979.947	
4	II	1876.836				4	III	1982.055			
5	II	1877.470				3		1986.399			
1	II			1882.240		6	II			1989.849	
5	II	1888.734				4	III	1989.957			
4		1891.501				4	III	1993.247			
3	III	1902.388				5	III	1996.405			
4	II	1904.790				6	II			2000.339*	
2	III	1912.905				5	II	2001.025			
2		1919.556				5	II	2011.348			
3		1924.517				4	II	2016.136			
5	III	1931.486				5	II			2017.60	
3	II	1935.299				4	II	2019.429			
4	III	1940.003				4	II	2021.399			
5	III	1943.459				4	II	2033.060			
5	II			1944.586		4	II	2037.089			
5		1950.323				5	II	2041.346			

* Blend.

have not been found. Of the $3d^5 4p$, practically all theoretically possible levels corresponding to those found in $3d^5 4s$ have been established. The final tables contain 320 levels and approximately 1500 classified lines.

A considerable extension by Edlén of the analysis of the second spectrum of iron (Fe II), using data from the same plates, is substantially completed and will be published in due course.

W. H. NEWHOUSE, Massachusetts Institute of Technology, Cambridge, Massachusetts.
Spectrographic studies of minor elements in minerals. (For previous report see Year Book No. 40.)

Analytical work has continued on the variations of minor elements in mineral deposits. The qualitative work has been completed on the examples described in Year Book No. 40. In order to leave no gaps in the data, all the minerals present to the extent of 5 per cent and more have been hand-picked and separately ana-

lyzed. Mixtures containing the less abundant and particularly the fine-grained minerals were analyzed to make certain that all elements present in the mineral deposits were identified. Over 800 analyses have been made, with examination for approximately 50 elements in each.

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Quantitative work has been completed

during the past year on the most widespread and abundant mineral, magnetite, and is now in progress on the feldspars and micas. Fifty magnetites from the varied geological environments selected for study were quantitatively analyzed for elements that showed some regularity in variation. These elements are zinc, nickel, cobalt, magnesium, vanadium, chromium, and strontium.

Some difficulty has been experienced in finding suitable internal standards for use in the quantitative work on these silicate minerals. This follows from the large variation in most of the main chemical elements present in the various members of

these groups. Further conclusions must await the analytical data now being obtained.

The results of work in cooperation with Dr. Clifford Frondel on the spatial distribution of minor elements in single crystals of galena (PbS) and calcite (CaCO_3) are described in a paper now in course of publication.

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DIVISION OF PLANT BIOLOGY

Central Laboratory located at Stanford University, California

H. A. SPOEHR, *Chairman*

For many years it has been generally assumed that the process of photosynthesis is fundamentally the same in all plants. Although it has been realized that in some of the lower forms of plant life, such as the purple bacteria, certain differences exist, the view has been commonly held that the photosynthetic apparatus, and also the products which are elaborated through this apparatus, are the same throughout the plant kingdom. Very little regard has been paid to the fact that the great diversity of plant forms which possess the power of photosynthesis represents a tremendous variance in evolutionary history and in range of adaptability, and considerable difference in chemical composition. It is, moreover, somewhat difficult to conceive that the geological evidences of photosynthetic activity, presumably represented by deposits of petroleum and carbonaceous material, had their origin in the photosynthetic process as we know it to occur today. That all plants do not contain the same photosynthetic apparatus has now been demonstrated by the discovery in diatoms, brown algae, and red algae of chlorophylls and yellow pigments which are different from the corresponding pigments existing in higher plants. Whether or not this difference in the photosynthetic apparatus is reflected in differences in the products elaborated remains to be established.

Pigments absorb the radiant energy essential to the production of carbon compounds by autotrophic organisms. Thus far little has been learned about how this absorbed energy is utilized in the synthetic processes carried out in plants. It is not

known to what extent each of the several green and yellow leaf pigments participates in this natural production of organic matter. It is believed that much can be learned from comparison of the light-absorbing properties of the individual pigments with the effect produced in the plant by light of various wave lengths. Such comparisons are dependent upon preparation of the pure pigments and upon precise determination of their spectral absorption properties.

For comparative purposes it is desirable to study organisms that differ considerably with respect to the pigments of the photosynthetic apparatus. Indications that different varieties of photosynthetically active pigments occur in different classes of algae have made necessary a more exact investigation of the pigments of these organisms. Advances that have been made in this investigation have been due largely to improvement of the sensitive chromatographic adsorption method of analysis and to use of spectral absorption measurements. By these means it has been possible to establish that most of the higher plants contain the same green and yellow leaf pigments, and to determine the differences which exist in regard to the photosynthetically active pigments between the higher and lower forms of plant life. These discoveries have raised a number of important questions regarding the variability of the photosynthetic apparatus throughout the plant kingdom and the possible bearing of this on the nature of the products which are formed. These findings may also contribute to a more exact systematic classification of some of these organisms

on the basis of their pigment complex and to better understanding of the phylogenetic relations between various algae.

Diatoms are widely distributed both in marine and in fresh waters. In the open ocean these minute plants usually are present in quantities exceeding those of all other forms of plant life, and it is probable that the total production of organic matter by diatoms exceeds that by any other class of plants. These organisms also flourished in past ages, as is indicated by the many extensive deposits of diatomaceous earth, consisting of the siliceous cell walls of diatoms. There is some evidence that many petroleum deposits have originated in organic materials manufactured by diatoms.

Despite the importance of diatoms in the carbon economy of nature, relatively little specific information is available concerning their chemical composition or the nature of their metabolism. Apparently the storage products of photosynthesis in diatoms are largely oils or oil-like substances, in contrast with the carbohydrates usually stored by higher plants. The question arises: are these different products the result of different photosynthetic mechanisms in the two groups, or merely of differences in secondary metabolic reactions? Differences in the photosynthetic pigment systems support the view that there may be fundamental differences between the photosynthetic process in diatoms and the corresponding process in higher plants or green algae.

Methods have been devised and apparatus has been constructed for the growing of relatively large quantities of these organisms in pure culture. The investigations are planned to yield information on the components of the photosynthetic apparatus, the composition of the photosynthetic products, and the type of photosynthetic reaction which occurs in these or-

ganisms. They are particularly favorable material for the investigation of the influence of different environmental factors on photosynthetic and metabolic activities, for which higher plants are in many respects less suitable. In order to gain a sufficiently comprehensive view of these functions of plants it is necessary to obtain data from plants representing different stages in the evolutionary scale.

The usual conception of the photosynthetic reaction is that the carbon dioxide absorbed by an illuminated plant is converted completely into carbohydrates. Many experiments have demonstrated the increase of carbohydrates during photosynthesis, but none of them has shown that carbohydrates are the only substances produced. A clear-cut demonstration of whether or not carbohydrates are the only products of photosynthesis is of fundamental significance to the understanding of the chemistry of this process. If carbon dioxide is transformed quantitatively into carbohydrates by the photosynthetic reaction, then all other substances elaborated by the plant must arise from subsequent transformations of carbohydrates. This would automatically separate all the chemical reactions occurring in plants into two main groups: the photosynthesis of carbohydrates, and the conversion of carbohydrates into all the rest of the organic substances which may be found in plants.

Because of the fundamental nature of this postulate, it is being made the subject of critical examination by as precise investigation as possible of the relation between the quantity of carbon dioxide absorbed by photosynthesizing organisms and the nature and quantity of organic material formed therefrom. Detailed observations on sunflower leaves have tended to support the postulate, for a close quantitative equivalence between the carbon dioxide absorbed and the carbohydrates

formed has been obtained. It remains to be demonstrated whether the small deviation from exact equivalence is due to the diversion of a small fraction of the carbon dioxide to the synthesis of substances other than carbohydrates, or whether it is due to the subsequent rapid conversion of the photosynthesized carbohydrates into other products. The sunflower plant which was used as experimental material for these tests is a very effective carbohydrate synthesizer. It remains to be determined whether in other plants, particularly in those of a lower evolutionary level, the photosynthetic process follows the same course.

The structural elements of higher plants are composed primarily of cellulose and varying amounts of polyuronides such as hemicelluloses, pectin, and gums. The polyuronides are extremely complex compounds composed of five- and six-carbon-atom sugars combined with uronic acids in various ways. Virtually nothing is known concerning the mode of formation of polyuronides, of the role they play in the economy of the plant, or of their dietetic value, although they constitute a very considerable part of the farm and forest crops. Within recent years compounds containing uronic acid units have gained added interest because of their significance for certain aspects of detoxication and immunology in the animal organism.

The idea has been advanced that the polyuronides are formed from starch, which of course is widely distributed in plants, through the oxidation of a part of the starch molecule. Efforts have been made to carry out such a reaction in vitro with a view to accomplishing the transformation of the starch molecule into a uronic acid. Uronic acids are characterized by the fact that when heated with 12 per cent hydrochloric acid they yield about 25 per cent of carbon dioxide. They can also

be identified by means of a very characteristic color reaction with naphthoresorcinol. By oxidation of starch, under carefully controlled conditions, with hydrogen peroxide in the presence of a small amount of an iron salt, an interesting product was obtained which lost carbon dioxide with great ease in amounts corresponding to those yielded by a uronic acid, but which proved not to be of this category of compound. Evidence was obtained that the starch molecule, in the course of its oxidation with hydrogen peroxide, splits into units of more than six carbon atoms, forming the same product which is obtained from maltose by the same oxidizing agent.

In furtherance of the objective of experimental taxonomy to extend knowledge regarding the processes of evolution in flowering plants, several kinds of experiment are in progress. During the past year studies on the nature of climatic races have been emphasized, because these are apparently among the most important steps in the building up of larger evolutionary units. For these studies naturally growing populations of the yarrow, *Achillea*, and of *Potentilla*, a close relation of the strawberry, have been investigated. These have been brought from diverse environments into cultivation under similar conditions. Observations on these, and genetic experiments on the *Madiinae*, are revealing the structure and relationships of climatic races. For such studies a much more intensive sampling of populations is necessary than was used in the previously completed transplant experiments. Such procedure makes possible a more adequate appraisal of the continuities or discontinuities that exist among climatic races.

In central California, populations of *Achillea* occur from the coastal bluffs at the Pacific to near the crest of the Sierra Nevada at 11,000 feet elevation, and east-

ward across the Great Basin and northward to Alaska. Two species meet on the lower western flank of the Sierra Nevada. These are marked by a difference in chromosome number that is an effective barrier to interbreeding. Yet the differences in form between the races within each species are very much greater than those between the contiguous races of the two species.

The climatic races of *Achillea* differ by many characters affecting both the form of the plants and their response to the environment. The distribution of the races closely parallels the major climatic belts found in a transect across California, as identified by the life zones. There are many colonies of each climatic race. Samples of colonies of *Achillea* taken at frequent intervals across California show that as one moves inland from the coast some miles, the dominating influence is roughly the distance from the sea. Farther inland, as in the Sierra Nevada, the dominating influence becomes altitude. Though each colony shows a marked diversity of heritable variation, as a whole it reflects the kind of habitat to which it is native.

It is too early to state whether the variation observed within and between climatic races is essentially continuous or discontinuous, but almost all the colonies under study contain a small percentage of individuals with characteristics of the adjoining climatic races. This observation frequently applies to such characters as time of flowering and winter dormancy, and may extend to other physiological characters. This suggests the possibility that within natural colonies new forms may originate through genic recombination and natural selection.

No precise information is at hand concerning the nature of the physiological differences that mark climatic races. This important gap in the information needed

for a clear understanding of evolutionary processes has been realized for some time. The intensive sampling and study of colonies of *Achillea* and *Potentilla* is giving essential information and materials for experiments in comparative physiology. In these experiments it is planned to compare the effects of one environmental variable on several basic physiological functions under controlled conditions, using plants of very different climatic races.

An apparatus for quantitative physiological experiments of this type has been designed and partly constructed. Radiation, temperature, and relative humidity can be regulated within broad limits. This equipment is to be used in the study of photosynthesis, respiration, and absorption of water by roots. Another apparatus, designed for exploratory experiments on the effect of different soil temperatures on growth of different climatic races, has been constructed and put into operation.

During past years considerable attention has been given to field investigations of the influence of environment on plants. Several of these projects have recently been brought to completion. The functioning of living organisms under the extremely severe environmental conditions of the desert presents an extraordinarily complex picture. The results of investigations in this field are now also being assembled for publication. It was essential, first of all, to obtain a picture of the vegetation of the arid regions on the background of the complex of environmental conditions of which the vegetation is a product. This has been done by means of extensive exploration and study of the composition, relationships, and distribution of the desert vegetation. In these investigations the study of the plant and of the environment have gone hand in hand.

The impression given by a desert landscape is largely made by its plants. Their

wide spacing, low stature, and many highly specialized forms create plant communities of distinctive aspect. Plants living near the limits of existence are more sensitive than others to small differences in environmental conditions. From this responsiveness follows the great variety of plant communities that distinguishes the different parts of the desert. In the field work of the past ten years it has been possible to examine at least a very high percentage of the communities found in the central and southern parts of the North American Desert. The physiognomy, structure, and composition of the communities have been determined. An understanding of the dependence of each community on a particular group of climatic and soil conditions has been approximated, but its precise determination in each case would require investigation far beyond the limits of the current projects.

The exploration of desert areas in Texas and on the Mexican plateau during the past four years has modified some of the conceptions based on earlier work in Arizona and Sonora. Particularly it has revealed a wider range of climatic conditions under which desert vegetation is found.

Low rainfall is the basis of desert, but it is neither a simple nor an isolated factor in relation to plants. Over much of the southwestern United States there is a close correlation between rainfall and vegetation, but in northern Mexico the correlation is highly modified. A study of available rainfall data for the entire North American Desert and the adjacent regions has been found necessary to an understanding of local conditions in any part of this area.

The forces of the environmental complex are constantly changing in relative intensity and effectiveness. Many of these environmental and climatic influences are clearly discernible in the form and dis-

tribution of living organisms. The world today represents the resultant of past and present forces. The past has significance in so far as it enables us to understand the present and in a measure to predict the future.

Plants of later geologic time provide one of the best means for reconstructing the topography and climate of the past. They are closely related to modern plants, whose environmental requirements may be readily determined and projected back into ages before man lived upon the earth. Many Tertiary forests were made up of elements which now live under varied conditions in widely separated parts of the world. In his search into the record of earth history, the paleobotanist must fit together the evidence of such forests, and draw a picture of yesterday colored by his knowledge of today.

Many millions of years ago the vegetation of Oregon included a mixture of such conifers as swamp cypress and redwood, trees now living on opposite sides of the continent. Mingled with them were black oaks and hickories like those growing in the cypress swamps of Indiana, together with tan oaks and maples whose modern descendants live with the redwood in California. The disappearance of these trees from Oregon during the long years since the Miocene has been largely the result of climatic changes associated with the uplift of the Cascade Range. Their survival in Indiana and California has been made possible by the continuance there of living conditions like those of the past. There is reason to believe that earth changes may further alter the distribution of forests, that the planet on which we live has not reached the end of its dynamic course, and that man as well as plants will continue to be modified by the trend of its future history.

Dr. Emmett Martin has been called to special scientific work in connection with the war; Malcolm Nobbs, assistant in taxon-

omy, has joined the Army; and R. F. Lucy, who has served as part-time artist, has joined the Coast Guard.

BIOCHEMICAL INVESTIGATIONS

H. A. SPOEHR, J. H. C. SMITH, H. H. STRAIN, W. M. MANNING, H. W. MILNER, AND G. J. HARDIN

PIGMENTS OF DIATOMS AND ALGAE

Diatom pigments. Considerable previous work had failed to give a clear understanding of the green and yellow pigments contained in diatoms. It was generally recognized that chlorophyll *a* was the principal green pigment (as in higher plants), that fucoxanthin was the principal xanthophyll, and that beta-carotene was the principal carotene. It was uncertain whether another green pigment observed in extracts of diatoms was chlorophyll *b* (the second green pigment of higher plants) or chlorofucine (a chlorophyll-like pigment first observed in brown algae and often reported to be a post mortem product). The nature of the diatom xanthophylls other than fucoxanthin and their relation to the common leaf xanthophylls was not known.

Analysis by Drs. Strain and Manning of diatoms (*Nitzschia closterium* grown in pure culture) has revealed that chlorofucine as well as chlorophyll *a* occurs in the diatom extracts. When the cells were killed under various conditions and extracted with methanol, the same proportions of chlorofucine and chlorophyll *a* were always obtained. Chlorofucine is, therefore, to be regarded as a normal constituent of the diatoms and not as a post mortem product.

Chlorofucine absorbs relatively very much less light in the red region of the spectrum than in the blue. Comparison of its spectral absorption curve with that of chlorophyll *a* revealed that, for methanol extracts of diatoms in the spectral region

between 455 and 490 m μ , chlorofucine absorbs considerably more light than chlorophyll *a*. This indicates that chlorofucine may play an important role in the photosynthetic activity of diatoms.

Especially sensitive adsorption methods for the detection of chlorophyll *b* in plant extracts were developed and applied to extracts of diatoms. No trace of this pigment was observed.

In conformity with earlier investigations, fucoxanthin was found to be the principal xanthophyll in the diatom extracts. In addition, however, this pigment was found to exist in at least three forms that are readily interconvertible by heat or by traces of iodine. Extraction of the cells under mild conditions always gave the same mixture of these three fucoxanthins. Unless a rapid interconversion takes place immediately upon death of the cells, all three fucoxanthins probably represent normal constituents of the diatoms.

The principal, most stable fucoxanthin represents about 90 per cent of the equilibrium mixture. It is adsorbed below the other two on columns of sugar. It shows a single definite spectral absorption maximum (452 m μ in ethanol). Each of the other two isomers shows a spectral absorption maximum about 6 to 7 m μ nearer the violet region of the spectrum. By analogy with other carotenoid and polyene compounds, these interconvertible fucoxanthins probably differ in the spatial arrangements about double bonds in the molecules.

Earlier work by Dr. Strain had shown

that the xanthophylls of higher plants can also be converted into isomeric pigments, but only the most stable isomers had been observed in leaves. The occurrence of several labile fucoxanthin pigments in diatoms, coupled with the fact that fucoxanthin appears to play a role in photosynthesis, suggests that this isomerization may be associated in some way with the function of the pigment in the photosynthetic reactions.

In addition to the three isomeric fucoxanthins, diatoms contain appreciable quantities of several other xanthophylls. One of these is weakly adsorbed and passes rapidly through the adsorption columns. Its spectral absorption curve is similar to that of zeaxanthin, but the absorption maxima are at slightly shorter wave lengths. Another xanthophyll present in somewhat larger quantities is remarkably similar to lutein, the principal xanthophyll of higher plants. This pigment and lutein show so nearly identical spectral absorption curves that they can easily be confused. They can be differentiated with certainty only by the slightly greater chromatographic adsorbability of the diatom pigment. Not one of the common leaf xanthophylls was detected in diatoms.

There is a marked difference between the spectral absorption curves of the fucoxanthins and those of the other xanthophylls and the carotene found in diatoms. For example, at a wave length of about 540 m μ fucoxanthins absorb considerable light, whereas the carotene and the other xanthophylls absorb virtually none. This fact has been made use of, in conjunction with the spectral curves of the several pigments, to calculate the amount of light absorbed by the different groups of pigments in the diatom extracts. At all wave lengths in the visible spectrum, chlorophyll *a*, chlorofucine, and the fucoxanthins together absorb 70 per cent or more of the

total amount of light absorbed by all the pigments in the methanol extracts. Whether or not these same relations hold in other solvents and in the leaf might be investigated with profit.

The photosynthetic apparatus of the diatoms has been varied by culture of the organisms in light of different spectral properties. Diatoms grown in "neon" light show a large increase in the lutein-like xanthophyll as compared with organisms grown in white light. When diatoms are transferred from white to "neon" light, this change takes place slowly and becomes substantial only after several generations of diatoms have been grown under the new light conditions. These observations point the way to two important fields of biological investigation. They indicate that products of probable functional importance may be varied a great deal in response to changes in external or environmental conditions. By careful control of external conditions it may become possible to vary at will the chemical products of Nature's greatest factory, the green parts of plants. Because changes of this nature may be involved in the early stages of the development or evolution of plant varieties, further studies of the physiological response of unicellular, autotrophic organisms to their environment may yield new methods and fresh views pertaining to the development of plant types.

Pigments of brown algae. Reports of the occurrence of both chlorofucine and fucoxanthin in brown algae prompted an examination of the pigments of several representatives of this group of plants. All the ten species examined contained chlorophyll *a* and chlorofucine. Chlorophyll *b* was not detected. All these species contained mixtures of the three fucoxanthins and all contained beta-carotene. Although lutein had been reported previously as a constituent of the brown algae, all the species ex-

amined contained instead several other xanthophyll pigments with spectral absorption properties similar to those of xanthophylls found in green leaves. One of these pigments resembled flavoxanthin; two of them were similar to violaxanthin. One of these violaxanthin-like pigments is very difficult to separate from the flavoxanthin-like pigment; the other is adsorbed near the principal fucoxanthin on the adsorption column. The lutein-like xanthophyll found in diatoms was not observed in appreciable quantities in the brown algae.

Like the diatoms, the brown algae are widely distributed and of great quantitative importance over large areas. This lends further support to the view that both chlorofucine and fucoxanthin may be important pigments in the carbon economy of nature.

A new chlorophyll from red algae. Further clues to the natural variability of the photosynthetic apparatus have been obtained from a cursory examination of the pigments of red algae. None of the species examined, representing some six or eight genera, contained either chlorophyll *b* or chlorofucine. In addition to chlorophyll *a* they yielded smaller quantities of another green pigment, a hitherto undescribed chlorophyll. This new chlorophyll shows maximum absorption far in the red and violet regions of the spectrum (maxima at 696, 456, and 401 m μ in methanol). Because the absorption maximum in red light is so far removed from that of chlorophyll *a* (665 m μ in methanol), the new chlorophyll is readily detectable by spectroscopic examination of methanol extracts of the algae. Relatively to the chlorophyll *a*, the quantity of the new chlorophyll varies a great deal in different species. The largest amounts have been found in two species of *Gigartina* (*Agardhii* and *papillata*) and in *Erythrophyllum*.

On adsorption columns of sugar, the

new algal chlorophyll is adsorbed not far above chlorophyll *a* and just below where chlorophyll *b* would occur. In the light of our experience with adsorption columns, this behavior suggests that the new pigment is probably closely related to chlorophylls *a* and *b*. When treated with acid this chlorophyll is converted into a gray pigment, pheophytin, that is very similar to or identical with the pheophytin obtained from chlorophyll *a*. This indicates a close relationship between chlorophyll *a* and the new algal chlorophyll.

In white light, solutions of the new chlorophyll are weakly fluorescent, but this apparent weakness of the fluorescent light may be due to the insensitiveness of the eye to light of such great wave length. In ultraviolet light, solutions of the new chlorophyll are bright red.

In view of the fact that the red-algal chlorophyll absorbs light in the far red region of the spectrum, where other pigments do not absorb appreciably, it should be possible by quantum-yield measurements to determine with certainty whether or not light absorbed by this chlorophyll is utilized in photosynthesis.

Implications. For many years it has been generally thought that the chlorophyll pigments in plants are subject to little or no variation. These investigations of diatoms, brown algae, and red algae indicate that the chlorophylls and also the yellow pigments in different algal classes are much more variable than was previously supposed.

These results justify the belief that the photosynthetic mechanism is not necessarily identical in all groups of plants. Theories concerning the mechanism of photosynthesis, and of energy transfer between pigments, should be re-examined in the light of these possible variations. Further investigations of the photosynthetic process in various algae are certainly to be desired.

The results of these pigment studies thus far also justify the belief that investigations of this type may provide an additional key to phylogenetic relations between the various algae. Taxonomists are able to place practically all known algae in a few well defined classes, but they are not able so easily to tell the probable relations between the various classes. Pigments related to the photosynthetic mechanism are of basic importance to the plant and must reflect some of the most important characteristics of its genetic makeup. It is reasonable to suppose that, in general, two groups of plants having several pigments in common are more closely related than groups having fewer pigments in common. Without considering other lines of evidence, at least two tentative conclusions can be drawn from this work thus far. One is that the green algae are less closely related to the groups of algae which have been investigated than they are to the higher plants. The other is that diatoms are probably more closely related to the brown algae than either group is to red algae or to green algae. These conclusions are based on the observations that (1) chlorophyll *a* and beta-carotene are probably the only pigments occurring in green algae and higher plants which also occur in perceptible amounts in diatoms and brown algae; (2) diatoms and brown algae have in common (in addition to chlorophyll *a* and beta-carotene) chlorofucine and the various fucoxanthin isomers; (3) red algae contain neither chlorofucine nor chlorophyll *b* but do contain another chlorophyll not found in diatoms and brown algae.

Obviously a detailed study of the green and yellow pigments in other groups of algae should yield many more clues regarding genetic relationships.

BIOCHEMICAL AND PHYSIOLOGICAL STUDY OF DIATOMS

To aid in the study of the chemistry and physiology of diatoms, it was found desirable to produce in pure culture relatively large quantities of diatoms (several grams at least). A gram of diatoms does not sound like a very large quantity until one undertakes to grow that amount in pure culture. In round numbers a gram (dry weight) of the marine diatom *Nitzschia closterium*, as commonly cultured, represents a hundred billion diatoms in 10 liters of sea water. Drs. Manning and Hardin have undertaken the isolation and culture of a number of different species of diatoms and other algae to be used in these investigations.

Culture methods. A glass culture vessel of 10-liter capacity has been assembled and put in operation for growing *Nitzschia closterium*, with provisions for maintaining the culture pure (i.e., uncontaminated with bacteria or other organisms). Air is supplied to the culture vessel by means of an aquarium pump, the air being filtered through sterile cotton before being admitted to the culture. Light is furnished by a spiral consisting of approximately 36 feet of "snow white" fluorescent tubing, which surrounds the vessel and furnishes an illumination approximately equivalent to one-eighth of full sunlight. Light of such intensity unfortunately brings with it considerable heat even from the relatively cool fluorescent light source. This heat, if not removed, would soon kill the diatoms in the culture. To conduct the heat away as rapidly as possible, chilled water is circulated through a cooler, constructed from two large concentric glass cylinders, which is inserted into the culture vessel. Additional light is provided by several turns of fluorescent tubing inserted in the inner cylinder. Provision is

made for drawing off portions of the culture from time to time and adding fresh sterile culture solution without introducing contamination. By this procedure it is possible to maintain the culture in approximately constant physiological condition and to obtain fairly large quantities of material at regular and frequent intervals. The procedure is very satisfactory for maintaining cultures of *Nitzschia closterium* except that the temperature problem is made somewhat difficult by the relatively low heat tolerance of this diatom. If the temperature of the culture rises much above 19° C. the multiplication rate is seriously reduced.

To supplement the studies with *Nitzschia*, and with the hope that perhaps some fresh-water diatom will have a greater tolerance for high temperatures and be equally satisfactory in other respects, the possibility of substituting a fresh-water form for the marine one is now being investigated. To date six species of fresh-water diatoms have been obtained in pure culture. Before mass culturing of these species is attempted it will be necessary to determine the best available conditions for their culture, and such studies are now under way. Besides giving a larger field from which to select forms most amenable to laboratory study, the obtaining and study of many different species of diatoms has the advantage of rendering more secure any generalizations that may be made about the metabolism of diatoms.

For purposes of comparison, it is also planned to culture unicellular algae other than diatoms. Sufficient equipment has been assembled for the simultaneous operation of three large culture vessels. One of the light sources consists of neon-filled tubing instead of fluorescent tubing.

In the preliminary culturing of diatoms one curious observation has been made

which merits mention and further study. It is generally true that a pure culture of an alga will grow in the presence of glucose and usually will grow much more luxuriantly than in a simple mineral medium where it must synthesize its own organic matter. It has been found, however, that the growth of the diatom *Nitzschia closterium* is completely stopped in rather low concentrations of glucose (0.1 per cent). This observation certainly bears on the supposed course of photosynthesis. One would expect any substance in the direct line of photosynthetic products to be utilized by the organism. If this is a valid assumption, it would appear improbable that glucose is involved in the photosynthetic process of the one diatom species tested to date. Obviously more work bearing on this point needs to be done.

Measurement of photosynthesis. An apparatus has been assembled for measuring photosynthesis in diatoms or other plankton algae under conditions which should permit the algae to continue normal growth during fairly extended periods of measurement. Another feature of the apparatus is provision for measuring rates both of carbon dioxide uptake and of oxygen evolution. The ratio of these rates gives an indication of the types of product being formed by a plant during a period of photosynthesis. The 2-liter reaction vessel which is employed for the photosynthetic measurements accommodates a volume of algal suspension large enough to permit direct chemical analysis of the material which has undergone a period of measured photosynthesis. The combination of chemical analysis and detailed photosynthetic measurements on the same material should provide information not otherwise obtainable regarding the photosynthetic and other metabolic products of diatoms.

THE NATURE OF THE PHOTOSYNTHATE IN SUNFLOWER LEAVES

For many years it has been known that carbohydrates make up a considerable portion of the organic matter produced by photosynthesis in higher plants. How nearly carbohydrates constitute all the organic matter thus produced has been tested in only a few cases. In these cases the amount of carbohydrate material recovered fell far short of the quantity anticipated from the amount of carbon dioxide absorbed.

Dr. Smith, assisted by Dr. S. S. Todd and Mr. D. Frazier, has undertaken an accurate investigation of the nature and amount of the organic matter formed during the illumination of sunflower leaves in relation to the amount of carbon dioxide absorbed. Indirect evidence of the nature of the photosynthate (the organic matter formed during photosynthesis) was obtained from a determination of the increase in dry weight produced in a leaf by the assimilation of a known quantity of carbon dioxide. For this purpose the two halves of a leaf, separated from the midrib, were used. One half was placed in an atmosphere containing carbon dioxide and illuminated, and the amount of carbon dioxide that it absorbed measured. The other half was kept in the dark and served as a control. From dry-weight determinations on the two portions of the leaf, the increase in dry weight of the illuminated portion was obtained. The procedure made it certain that the transfer of material to and from the leaf could take place only through the atmosphere surrounding the leaf. That this was true was demonstrated by combustion analyses, which showed that the increase in the carbon content of the illuminated leaf was equal to the decrease in carbon content of the atmosphere surrounding the leaf.

Several determinations of the ratio of the increase in carbon content of the illuminated leaf to the increase in dry weight yielded a value for the percentage of carbon in the photosynthate of 41.38 ± 0.60 per cent. This value clearly approximates the percentage of carbon in a disaccharide (cane sugar, for example, contains 42.10 per cent carbon) and suggests that the photosynthate may be carbohydrate alone. However, the carbon content of the dried sunflower leaves used as controls for the photosynthesis experiments was 45.74 ± 0.24 per cent. On an ash-free basis this corresponds to a carbon content of 51 or 52 per cent for the organic material of the leaf. This value is considerably higher than the carbon content of the photosynthate, or even of cellulose (44.4 per cent), and indicates that subsequent metabolic processes of the leaf may transform the organic matter formed during the photosynthesis into a more highly reduced state.

Direct analysis has shown that the organic matter formed by the sunflower leaf during a short period of illumination (about 60 minutes) consists largely of carbohydrates, 91.87 ± 1.46 per cent. By suitable analytical procedures these carbohydrates can be separated into several fractions. The percentage of the assimilated carbon attributable to each of these fractions is as follows:

Fraction	Percentage
Glucose + levulose	9.98
Sucrose	51.92
Unidentified sugar	3.12
Unidentified polysaccharide . .	1.38
Starch	25.49

In these experiments the leaves, after removal of the midrib, were quartered and alternate quarters used as control and as photosynthesizing agent. Quartering rather than halving insured a greater similarity

of the two leaf portions. Removal of the midrib avoided the loss of organic material by transport but deprived the leaf of external water supply, with consequent water deficit. This may have altered the normal ratios of the carbohydrates to one another.

The residue from the illuminated portion of the leaf, after removal of all soluble material, contained a portion of the photosynthate. It is not known whether this part of the photosynthate consisted of carbohydrate (cellulose, hemicellulose, etc.) or of protein, but nitrogen analyses indicated that possibly a part of it might be protein. At the present stage of the investigation, values for the carbon content of this portion of the photosynthate must be assumed. Calculations based on the percentage of carbon in cellulose and in protein would assign to this portion of the photosynthate 6.49 and 7.61 per cent, respectively, of the total increase in content of carbon. The total recovery of carbon would be then either 98.36 or 99.48 per cent, with a probable error of about ± 3 per cent.

In the experiments just described, the leaves photosynthesized for about an hour and respired for an additional 20 minutes before being killed. During this time respiration and other nonphotosynthetic transformations of carbohydrates undoubtedly occurred. These transformations may have caused the recovery of carbohydrate to be less than the amount actually formed by photosynthesis, and an attempt was made to determine whether or not this was so. For this purpose the percentage recovery of assimilated carbon in the form of carbohydrates was determined after a 4-hour dark period immediately following a period of photosynthesis. In some instances, during the prolonged respiration, a much greater loss of carbohydrates took place than was attributable to respiration as measured by carbon dioxide liberation.

This suggests that a rapid synthesis of other substances takes place from carbohydrates and accounts in certain experiments for the exceedingly low recovery in the form of carbohydrates. In other cases the liberation of carbon dioxide from the leaf exceeded the loss of carbohydrates, and a recovery of an apparent excess of carbohydrates resulted. Whether part of this excess arose from an additional synthesis of sugar in the dark is not known. The results of these experiments were too inconsistent to justify generalization, but they were sufficiently clear to explain the variations in the recovery values of carbohydrates. The factors influencing these changes are still beyond our knowledge.

The results of these experiments show that the preponderant products of the photosynthetic activity of sunflower leaves are carbohydrates, and that if other substances are formed they constitute only a small part of the photosynthate.

Although these experiments demonstrate that photosynthesis by sunflower leaves may produce a quantity of carbohydrate equivalent to the quantity of carbon dioxide absorbed, the carbohydrates formed may or may not incorporate the same carbon atoms as are absorbed. It is conceivable that the assimilation of carbon dioxide may initiate a chain of reactions which culminates in a quantitative yield of carbohydrates without incorporating into these carbohydrates the particular carbon atoms absorbed. The present experimental methods are ill suited to distinguish between these two possibilities, direct and indirect formation of carbohydrates, but by the use of labeled carbon such a distinction should be possible.

Because of war conditions this tracer element has not been available. It may be feasible to prepare radioactive carbon, C^{14} , by means of the Stanford cyclotron, and experiments are now under way, in which

the Department of Physics of Stanford University is generously cooperating, for the purpose of examining this possibility.

PLANT POLYURONIDES

Although polyuronides such as hemicelluloses, gums, mucilages, and pectin are widespread and constitute a very appreciable part of the framework of higher plants, virtually nothing is known regarding the mode of formation of these substances. There has been some indication that they may be derived from starch through a series of steps involving the oxidation of the primary alcohol groups with the formation of uronic acid units. An effort has been made by Dr. Spoehr and Mr. Milner to determine whether the primary alcohol groups of starch can be oxidized *in vitro* to form substances containing uronic acids.

The most promising oxidizing agent was found to be hydrogen peroxide in the presence of a small amount of ferrous sulfate. With this reagent the starch was readily oxidized at 20° C. and was simultaneously hydrolyzed. By treatment with boiling 12 per cent hydrochloric acid polyuronides are decarboxylated and yield 25 per cent of carbon dioxide and appreciable amounts of furfuraldehyde. In a series of oxidations of starch, using 1 to 8 mols of hydrogen peroxide per glucose unit, the oxidation product giving the highest yield of carbon dioxide by the method just mentioned was obtained with about 5 mols of hydrogen peroxide. This yield of carbon dioxide amounted to 22.56 to 25.20 per cent in various preparations. This oxidation product proved, however, not to be a uronic acid, as it did not give the characteristic reaction with naphthoresorcinol, and yielded but small quantities of furfuraldehyde. As by-products in this oxidation, carbon dioxide, formic acid, and oxalic acid are also formed, increasing in

quantity with the use of larger amounts of the oxidizing agent.

The oxidation product obtained with 5 mols of hydrogen peroxide is very soluble in water, methanol, and ethanol, and insoluble in ether, acetone, and nonpolar solvents. Unfortunately it could not be crystallized. Neither could well defined metal or alkaloid salts be obtained, nor definite compounds with phenylhydrazine, its substituted derivatives, or other organic compounds. This is apparently due to the fact that the oxidation product is very easily decarboxylated. In water solution it loses carbon dioxide slowly at room temperature, loses it more rapidly at 50° C., and at 100° yields about 18 per cent; this is to be compared with a yield of 24 per cent carbon dioxide by treatment with 12 per cent hydrochloric acid. A water solution of the oxidation product when treated with brucine, strychnine, pyridine, phenylhydrazine, aniline, o-phenylenediamine, or o-toluidine rapidly liberated 3 to 5 per cent carbon dioxide.

When exposed to light in the presence of air, a water solution of the oxidation product yields large amounts of carbon dioxide. At 20° C. about 75 per cent of the substance is thus oxidized to carbon dioxide in 32 hours, the photooxidation proceeding approximately linearly with time. The oxidation product has strong reducing properties; it reduces silver nitrate in the cold, also potassium permanganate, iodine, Benedict solution, and sodium 2,6-dichlorobenzenoneindophenol. It showed no vitamin C properties when tested on guinea pigs.

A molecular weight of 306 was obtained by the cryoscopic method in water solution, and although the electrometric titration curve was of indefinite shape, an equivalent weight of 140–150 was obtained, indicating a dicarboxylic acid. In view of the fact that it loses 2 mols of carbon dioxide

when treated with 12 per cent hydrochloric acid and that at least half of this carbon dioxide is lost with great ease, the substance is probably in part a β -keto acid. Combustion analysis gave results agreeing well with the empirical formula $C_{10}H_{12}O_{12}$.

Both glucose and maltose were oxidized with the same oxidizing agent. With 3 mols of hydrogen peroxide, in comparison with starch, glucose yielded about 8 times as much formic acid, very little oxalic acid, and a main oxidation product which yielded only 10 per cent of carbon dioxide when treated with 12 per cent hydrochloric acid. Maltose, on the other hand, when oxidized with 8.4 mols of hydrogen peroxide (equivalent to 4.2 mols per glucose unit), yielded, besides small amounts of formic and oxalic acids, a main oxidation product having the same properties and yielding the same percentage of carbon dioxide on decarboxylation as the product obtained from starch. The molecular weight of the oxidation product obtained from maltose was also very nearly the same as the value obtained for the starch oxidation product, and the combus-

tion analyses of the two substances were in close agreement.

These findings may prove to have some bearing on the constitution of the starch molecule, a problem which has occupied chemists for many years. The enzymatic hydrolysis of starch yields maltose, whereas hydrolysis with acids usually yields glucose. When starch is treated with hydrogen peroxide in the presence of small amounts of iron, the main product formed represents a molecule which is larger than could arise from the oxidation of glucose. This indicates that with this reagent the starch in the course of oxidation splits into units of more than six carbon atoms. Although it is impossible to determine at what stage of the oxidation splitting of the starch molecule occurs, the fact that the same product is obtained from starch and maltose indicates that the oxidation product of starch is derived from a maltose unit. Evidence obtained thus far does not warrant assigning a structural formula to the oxidation product obtained from starch, although several $C_{10}H_{12}O_{12}$ formulas can be written which are consistent with the observed properties.

EXPERIMENTAL TAXONOMY

JENS CLAUSEN, DAVID D. KECK, WILLIAM M. HIESEY, AND E. V. MARTIN

Fundamental to our understanding of plant relationships is knowledge concerning the make-up of climatic races of the same or of closely related wild species. In climatic races we can study evolutionary divergence in its early stages, and then progress to differences of greater order such as are found in species and genera. An understanding of the principles that govern the distribution of such races is basic not only to an understanding of evolution, but also to successful plant breeding, because cultivated plants, like wild ones, are healthier and more productive

when they fit the environment in which they are grown. During the past year considerable progress has been made in the study of genetic variations of natural populations of *Achillea* and *Potentilla glandulosa*.

The general organization of plant groups into recognizable units of successively higher order as disclosed by experimental means has already been outlined (Year Book No. 39, pp. 158-163, and No. 40, pp. 160-170). Such categories include local populations, climatic races, species, species complexes, and genera. The relations be-

tween the higher categories have been most effectively studied in the annual species of the Madiinae and will be the subject of publications now in preparation. For the study of the lower categories, such as the climatic races or ecotypes within one species, perennials such as *Achillea* and *Potentilla* are more suitable because their species range over several climatic zones and have evolved a much richer array of races. From the appearance of plants in the wild, one would conclude that *Achillea* has evolved series of continuously intergrading races in certain areas.

HEREDITARY COMPOSITION OF CLIMATIC RACES

Basic to the whole idea of evolution by natural selection is individual variability. Modern genetics has been built upon the study of the inheritance of individual differences so distinct that they can be readily separated and classified—the so-called mutants. The neo-Darwinian theories of natural selection are based mainly on facts known about such characters. Although the mutants analyzed in laboratory experiments are indispensable for the study of the laws governing inheritance in general, their survival value in natural selection is very questionable. Therefore, before results from laboratory experiments can be utilized in explaining evolution, they need to be corroborated by studies on characters typical of wild plants.

After extensive studies on the cytogenetics of wild populations, it appears that the theories of evolution by mutation and recombination have generally been oversimplified. This becomes evident when contrasting climatic races of a species are crossed, and the hybrid segregants of the second and third generation are studied. Climatic races differ by many characters, and the segregations indicate that even small morphological differences are deter-

mined not by one, but by several pairs of genes, each changing the individual slightly. The effect of the individual gene in wild races is therefore less upsetting to existing gene balances, but also less distinct in expression, than that of genes utilized in orthodox genetic experiments.

The number of genes determining each character is limited, however. It has been found, for example, that differences in habit, mode of branching, earliness of flowering, color of flowers, shape of seeds, and other characters found between climatic races are frequently governed by no more than three or four pairs of genes. In some races the genes for different characters may show linkage, in others not. The important fact is that the inheritance of these characters is neither very simple nor so complex that small but discontinuous steps of evolution, such as are postulated by classic genetic theory, are ruled out.

Seedlings of wild populations of both *Achillea* and *Potentilla glandulosa* from many points in the Coast Ranges and from approximately 1000-foot altitudinal intervals along our Sierra Nevada station transect are being grown at Stanford for careful comparative study. Seedling cultures of *Achillea* attain maturity within two years, but the *Potentillas* require an extra year for their full development and the first of them are just now beginning to manifest their characteristic differences in the Stanford garden.

As previously pointed out (Carnegie Inst. Wash. Pub. 520, pp. 296-300), the climatic races of *Achillea* in California belong to two species which apparently do not overlap, but together cover the entire transect from the coast to the desert plateaus. At latitude 38° north, *Achillea borealis*, with 27 pairs of chromosomes, covers the distance from the coast to the Sierran foothills, and the 18-chromosome

from this transect. These were grown in a uniform garden at Stanford. The class frequencies for 10-centimeter intervals of plant height are given in the vertical columns, all but two of the populations consisting of approximately 60 individuals each. The curve passes through the mean height of each population, which is indicated by the scale at the sides of the graph. The geographical location from which the seeds for each population were taken is shown in relation to the profile of a transect across California below. The horizontal distances in the graph approximate functions of the topography of the cross section of California, starting at the Pacific to the left. The dominating influence in the left-hand part of the figure is the increasing distance from the sea, whereas in the right half the dominating influence is the increase in altitude of the habitats. The headings of the figure indicate the limits between the two species, and the climatic races represented. Although the sampling is more intensive than in the transplant experiments, each major race is represented by a minimum number of populations.

The extreme maritime race of *Achillea borealis* clings to the wind-swept, fog-laden, narrow strip of coast overlooking the ocean. Its genetically low habit is probably a selective response to the prevailing strong winds. The population from the Bodega coast north of San Francisco Bay is the most extreme of those illustrated, but an even more extreme form occurs 350 miles farther north on the bluffs near Port Orford, Oregon. The most maritime forms are low and spreading, with massive, thick-textured, dark-green rosette leaves, and late flowering such as is typical of maritime ecotypes of other species. In populations from somewhat less wind-exposed coasts, such as the dunes and bluffs of San Francisco and the coast at Montara,

the selection appears to have been less rigid. Although some individuals as extreme in appearance as those from the Bodega coast and Port Orford occur here, a slightly taller and earlier form is more common. This, however, has the characteristic maritime type of leaf.

As one moves inland from the windy coast, the maritime race is rapidly replaced by that of the outer Coast Ranges, a very tall but still fairly late-flowering form, which appears able to make maximum use of the abundant moisture in the coastal fog belt. The San Gregorio population in figure 1 is typical of this race. There is hardly any overlapping in height at Stanford between plants of this population and those from the most exposed coasts such as Bodega, but its smaller plants are a match for the taller ones from less exposed shores such as those of Montara and San Francisco. The leaves of the outer Coast Range race, however, generally have much less dense segments than those of the maritime race.

The maritime and outer Coast Range races meet a very short distance from the sea. The populations at these localities contain mixtures and recombinations of the two races. This is illustrated by the two populations from the base of Montara Mountain, a locality approximately $\frac{1}{2}$ mile from the sea. One population was obtained by sowing seed gathered from plants of low stature only, and the other was derived from seed collected from tall individuals. When grown at Stanford, the two populations differed significantly in height, as can be seen in the figure. Moreover, the offspring from the short plants corresponded to the maritime race, whereas those from the tall ones resembled plants of the outer Coast Range race.

In the Upper Sonoran zone of limited rainfall around the valleys of the inner Coast Ranges and in the Sierran foothills

another recognizable race occurs. It flowers months earlier than the maritime forms, while there is still adequate moisture from early spring rains, and then dries up, becoming dormant during the summer and fall period. This is in contrast with the maritime race, which is evergreen when grown at Stanford, and also in contrast with the outer Coast Range race, which is intermediate between the maritime and foothill forms in earliness and dormancy. The three populations of the inner Coast Range and foothill race indicated in figure 1 are also distinguished from the maritime by their grayer pubescence and few rosette leaves. Each of these populations shows an appreciable amount of individual variability, the Colusa County population including individuals approaching those found in the outer Coast Ranges.

A giant form of *Achillea borealis* occurs in the Lower Sonoran zone in limited areas along streamways on the hot San Joaquin Valley floor. A population of this strain, which is early and in its native habitat reaches a height of 2 meters, has recently been acquired, but is too immature at this writing to be included in the tabulation.

In passing to elevations of 3000 feet in the Sierra Nevada, as at Groveland, where the ponderosa pine and incense cedar replace digger pine and blue oak, one encounters the Transition zone race of another species, the 18-chromosome *Achillea lanulosa*. Populations of this species up to 5000 feet closely resemble the foothill forms of *Achillea borealis*, although the cytological difference between them prevents free exchange of genes through crossing. Plants of the Transition zone race can be distinguished from the foothill race principally by chromosome number and by their much later flowering

when grown at Stanford. Also, they usually have smaller heads and more slender stems and remain green later in the summer.

All the climatic races of *Achillea borealis* indicated in figure 1, and also plants of the Transition zone race of *A. lanulosa* from lower elevations, remain green and active at Stanford during the winter. From higher elevations in the Transition zone upward, the plants show an increasing degree of winter dormancy and a lowering of stature at Stanford.

In populations from the Transition zone, a mixture of winter-green and winter-dormant plants is found, as well as individual variation in height. This has been observed, for example, in the Mather and Hetch Hetchy Road populations. At approximately 6000 feet altitude in the Canadian life zone, characterized by red fir and Jeffrey pine, the transformation from winter-green to winter-dormant plants is almost completed, and one encounters a climatic race that at Stanford attains a mean height approximately 25 centimeters less than that of the populations from the Transition zone. The Canadian zone race, exemplified by the Aspen Valley population, goes dormant during the winter at Stanford and is generally late and very erratic in its flowering. However, single plants comparable with those typical of the Transition zone are found mixed with the others, just as one finds mixed stands of Jeffrey and ponderosa pine. Near the upper edge of this zone there is considerable intermixing of this race with the subalpine race above it. For example, the variable Yosemite Creek population from 7200 feet includes plants indistinguishable in height, leaf form, pubescence, and time of flowering from Tenaya Lake plants of the subalpine race at an elevation of 8200 feet.

At around 8000 feet, in the lodgepole pine belt, the stems of *Achillea* are much shorter and more slender, and have more contracted inflorescences. Most conspicuously, the leaves are grayer-pubescent, much smaller, and proportionately much narrower. This trend continues to the upper limit of the species distribution at 11,000 feet. Parallel with these morphological differences is a lengthening of the dormancy period during the winter at Stanford, as compared with that of the plants of the Canadian zone. Taxonomically these subalpine and alpine forms are known as subspecies *alpicola*.

It appears that this high-montane subspecies is composed of more than one climatic race, a subalpine and an alpine. Figure 1 shows that there is a distinct difference in height and ability to flower at Stanford between the plants from Tenaya Lake, on the one hand, and those from Tuolumne Meadows and Slate Creek Valley on the other. This is also emphasized by differences in earliness of flowering, especially as observed on transplants at our alpine station in Slate Creek Valley. Both the subalpine and alpine races are erratic in their flowering at Stanford, an evidence of their being out of harmony with this environment. Some plants are extremely early, others very late, and more than 50 per cent of the plants of the most alpine population are unable to produce flowering stems at all. Also, the number of stems is very small in plants from high altitudes as compared with those from lower altitudes.

Each population from these higher altitudes contains a few individuals typical of the neighboring climatic race. A few characteristically alpine plants were found in the Tenaya Lake population, and a few of subalpine reaction from Tuolumne Meadows and Slate Creek Valley, but

more than 80 per cent of the individuals in each population were characteristic of the climatic race to which they were assigned.

At the uppermost limit of the range of *Achillea lanulosa*, 11,000 feet, the most dwarf, most pubescent, and apparently most uniform race of all is encountered, but transplants from this altitude are at the present writing too immature for study. The apparent uniformity of this extreme alpine recalls the relative homogeneity of the extreme maritime population of *A. borealis* from the Bodega coast, and suggests that at these extremes natural selection has been more rigid and the influx of genes from other racial elements more limited.

Finally, in the Great Basin, at 6000 to 8000 feet elevation, forms occur that are genetically taller than the alpine and among the most frost-resistant of all *Achilleas*. Plants of this race have been observed at the alpine station in early bloom and apparently undamaged after temperatures as low as -10°C. , when other races were badly frozen. It is obvious that frost-hardiness is a desirable character for a plant native to the interior plateaus which have severe winter temperatures but very little snow cover. Cultures of this climatic race are still too immature to be included in the tabulations.

In summary, we find that the climatic races of *Achillea* reflect the changes in climate associated with the topography of California to a remarkable degree. Each major climatic belt has its climatic race of *Achillea*, of characteristic appearance and reaction. In gross features, the distribution of the climatic races appears to follow that of the characteristic trees and other indicator plants of the different life zones, although the agreement is not absolute.

No natural population of *Achillea* is uniform, but apparently each has sufficient variability and genes to provide for a considerable array of forms in any one environment. Some of this variability is evidently physiological. Judging from the reactions observed in the Stanford garden, this variability usually appears large enough to include a few individuals characteristic of the neighboring climatic races. Possibly more individual variability can be observed in the garden than in nature because of the elimination that takes place under natural competition. The variability demonstrated to occur in wild populations, however, suggests a range of physiological tolerance which, by genic recombination, may give rise to new populations successful in other habitats.

There is considerable evidence that forest trees and grasses have climatic races similar to those observed in *Achillea* and *Potentilla*. Several years' data have been gathered on the climatic races of the tufted hair grass, *Deschampsia caespitosa*. This species, like *Achillea*, occurs throughout the northern hemisphere. A few races from Scandinavia, from arctic Lapland, and from a transect across California from the coast to 10,000 feet altitude in the Sierra Nevada are being grown at the transplant stations. In this species the races native to the California mountains are constantly being exterminated by rust at Stanford, although they are not attacked in their native habitats. Though the other races succeed at this station, the loss of the mountain races here is a handicap in the investigations. These observations and those on other plants suggest that the problem of resistance to diseases may be closely allied to the fitness of a plant for the climate in which it is being grown. This point of view might find valuable ap-

plication in the breeding of disease-resistant crop plants.

PHYSIOLOGICAL STUDIES

The knowledge that has been gained concerning the nature of climatic races makes it possible to formulate a program of investigation on their functional differences. Relatively simple methods for comparing basic physiological functions of climatic races give promise of making it possible to relate the physiological reactions characteristic of climatic races to the ability of the races to survive in different environments.

The general method of approach will be to compare the effects of one environmental variable on several selected functions of contrasting climatic races under controlled conditions. Two types of experiment are planned: one is to be exploratory and qualitative, and the other is to be controlled and quantitative. The object of the exploratory experiments is to determine the general limits within which it may be profitable to conduct the more precise work. The quantitative experiments will be conducted in chambers in which radiation, temperature, and relative humidity are regulated, so that these conditions may be changed or closely reproduced at will.

In the study of altitudinal and latitudinal races, it is assumed that the principal controlling environmental factor is temperature. This assumption is made because of the great similarity in the nature of the variation between the two kinds of races, and because temperature is the outstanding variable common to both series. It is probable that other factors may also be important, but it is felt that the effects of temperature should be thoroughly investigated first. The functions to be studied are assimilation, respiration, and absorption of

water by roots. Water absorbed by roots will be measured volumetrically as it is removed from culture solutions. By measuring carbon dioxide exchange and rate of water uptake simultaneously, possible correlations between these functions may be studied.

The most contrasting altitudinal races of a species will be compared first; intermediate races may be introduced later on. Genetically different individuals of one population may also differ in their physiological activity over a range of temperatures, and possibly even in their tolerance to extreme temperatures. It is hoped that such data will reveal the physiological differences on which the evolution and existence of climatic races seem to depend.

The exploratory type of physiological experiment has been initiated by the construction of an apparatus designed to provide a gradient in soil temperatures for studies on the effect of this factor upon growth of climatic races of *Achillea* and *Potentilla glandulosa*. This apparatus consists of a sand-filled tank, well insulated and fitted with an insulating lid with holes for the plants. At each end of the tank is a compartment in which the temperature is maintained at a constant value. One end is kept near 0° C. by means of a refrigerating compressor; the other is kept near 40° C. by electric heaters. Both temperatures are kept nearly constant by thermoregulators. A gradient of temperature through the sand is established by the presence of these end compartments. The sand-filled part is partitioned into smaller units in order to restrict the roots to a fairly narrow range of temperature. The sand is watered from below with nutrient solution by a hydrostatic system.

Seedlings or rooted cuttings of altitudinal races are grown in rows running the length of the tank from the warm to

the cold end. The apparatus is located in a small greenhouse in a place where the aerial parts of the plants are exposed to as nearly the same environment as possible. In this manner, relations between soil temperature and growth of roots of the various climatic races are being studied in connection with the growth of tops in a given aerial environment.

An apparatus for experiments of a quantitative nature has been designed and partly constructed. It consists essentially of a cubical air chamber 14 inches on each side, in which air temperature, relative humidity, and radiation intensity are to be controlled. It is designed to maintain air temperature constant at any value between 0° C. and 50° C., relative humidity between 20 and 80 per cent, and radiation between zero and half or more of full sunlight intensity. Two sides and the top of the chamber are of glass to permit entrance of radiation from lamps.

The container holding the roots projects through the floor of the chamber into a solution the temperature of which can be controlled independently of that of the air around the shoots. The air system is to be made airtight so that changes in concentration of carbon dioxide may be measured.

Individuals of races for use in these experiments will be grown in nutrient solution in a greenhouse. After being thus exposed to closely similar environmental conditions, these will then be introduced into the control chamber for a study of their physiological functions.

It is hoped that in the future these investigations may be extended to the study of growth of climatic races under conditions which will permit control of all factors of the environment during their entire life cycle. It will then be possible to investigate the carbon dioxide exchange and

water absorption of plants grown under a wide range of reproducible environmental conditions. The development of the control chamber is temporarily suspended because Dr. Martin, who designed and was building it, is now engaged in war research.

INVESTIGATIONS ON THE MADIINAE

Efforts of the staff are being concentrated on the analysis of many years' accumulated data on *Layia* and related genera, and on the completion of experimental work needed to round out the investigations on the other Madiinae. The results on the *Layia* group are being prepared for publication.

The investigations on *Layia* were discussed rather fully in Year Book No. 40, pages 160-170. Developments in the study of the genus during the past year include the completion of genetic analyses of pappus characters in geographical strains of *Layia platyglossa*, data from F₂ populations of hybrids in the *Layia gaillardoides* group, and the establishment of the genetic relationship of a newly discovered *Layia* whose morphology is so unlike that of other members of the genus that even its inclusion in the subtribe Madiinae was open to question (cf. Year Book No. 40, p. 168). From hybrids now obtained it appears that this plant is probably a mere subspecies of *Layia glandulosa*, with which it seems to be highly interfertile. It is apparently an extremely reduced and slender form of that species, with ray florets completely lost and the pappus much abbreviated.

The newly synthesized *Madia citrigracilis*, mentioned in the previous report, is being grown in its third generation for further tests on its fertility and cytological regularity, and for comparisons with its parent species, *Madia gracilis* and *M. citriodora*, as well as with the native *citrigracilis* obtained in the wild.

Miss Marguerite E. Hartung, formerly of the University of Hawaii, has been engaged during the current year in microtechnical work in connection with cytological studies on the Madiinae, and has aided in the analyses of hybrid populations of *Layia* and *Madia*. She succeeds Mr. Malcolm Nobs, who now is in the United States Army. Exploratory studies by Mr. Nobs on the cytogenetics of the wild lilacs of California, the genus *Ceanothus*, have been incorporated in a recently published monograph on this complex group by Professor Howard E. Mc-Minn, of Mills College.

STUDIES AT THE TRANSPLANT STATIONS

Final data are being obtained this year on the selection experiment involving an F₂ hybrid population between a foothill and an alpine form of *Potentilla glandulosa* (cf. Year Book No. 39, p. 162). These will be subjected to a thorough analysis before publication.

New clone transplants consisting of 30 individuals each of fourteen populations of *Achillea* have been set at the Stanford, Mather, and Timberline transplant stations this year. These populations are from altitudinal intervals of approximately 1000 feet along the station transect, with a strain from the Danish seacoast and another from Lapland included. All these transplants are to be studied with special reference to genetic variation within populations and to differences between populations as a whole in these contrasting environments. It is intended to coordinate these studies closely with the physiological investigations in the hope that a clear picture may be obtained of the interrelations between genetic variation in natural populations and climatic races on the one hand and physiological functions on the other. This should lead us to a clearer understanding of the dynamics of evolution.

DESERT INVESTIGATIONS

FORREST SHREVE

In previous years the investigation of the Sonoran and Chihuahuan deserts has consisted almost entirely in work on the vegetation and in the effort to secure a complete enumeration of the vascular plants. The core of these projects, however, is a knowledge of the influences of climate and soil in determining the vegetational and floristic features that have been found. Practical considerations have made it impossible to attempt an adequate system of instrumentation over such large areas or even to carry on a restricted system for more than a few years. Official American and Mexican climatic data are very helpful, although they are lacking in regard to many phases of great biological importance. Also, desert climatological stations, like all others, are located at centers of population rather than at critical places in the climatic map. Many of the data obtained at the Desert Laboratory over long periods are of biological significance, but they are not all applicable to other parts of the desert.

Work on the vegetation and flora of the desert areas has been continued, and during the past year an appraisal has been made of all data bearing on the physical conditions of the Sonoran and Chihuahuan deserts. A detailed study of the data has been completed for the rainfall only.

FIELD WORK

In the summer of 1941 Dr. Shreve continued the exploration of the eastern edge of the Chihuahuan Desert and examined the elevated plateau of Hidalgo and eastern Queretaro. The principal objective was to learn the character of the Hidalgo desert and the relation between the northern and southern types of desert in Mexico.

The northern type, characteristic of the lower elevations of Chihuahua and Coahuila, does not extend south of the state of San Luis Potosí. Much of the desert of Hidalgo is edaphic rather than climatic. On extensive areas of shallow limestone soil, the vegetation is desert, and similar to that of central San Luis Potosí. On deep and retentive volcanic soils at the same altitude, the vegetation is arid bushland of a type which bounds the desert at many places along its eastern and southern edges. Where streams or abrupt canyons are found in the arid highlands of Hidalgo, the vegetation is closely related to the northern fringe of tropical forest common in northern Veracruz, and has no relation to the vegetation of similar habitats in the desert. Also the floristic relationship of the moister habitats is preponderantly with the subtropical lowlands rather than with the desert. Locating the southern limit of the Chihuahuan-Coahuilan type of desert has been made difficult by the recurrence of desert valleys separated by hilly and mountainous areas of bushland or forest. Sufficient study of the region has now been made, however, to warrant a definite delimitation of the southern boundary of the Chihuahuan Desert in central San Luis Potosí.

Proximity to Mexico City gave an opportunity to visit the Biological Institute of the National University of Mexico, from which have emanated several important investigations of the vegetation of central and southern Mexico. Dr. Isaac Ochotena, Director of the Institute, has long been very helpful, both officially and scientifically, in connection with our work in his country. Discussions with him and with Dr. P. F. Villagran and Professor L. An-

cona, of his staff, were full of valuable comments and suggestions, and were particularly helpful with reference to the status of the arid regions of Puebla and Oaxaca.

Visits were also made to the National Meteorological Observatory of Mexico, at Tacubaya. Through the courtesy of Sr. José C. Gómez, Chief of the Meteorological Service, we were supplied with a complete transcript of the rainfall and temperature data for all the older stations in the Sonoran and Chihuahuan deserts. This material is invaluable in a study of the environmental conditions of the desert regions.

Dr. I. M. Johnston spent 10 weeks in the field in central Coahuila and eastern Chihuahua in the past summer, accompanied by Dr. Kirk Bryan, of Harvard University, who was engaged in physiographic investigations in the same area. The desert basins and low mountains lying between Musquiz and Cuatro Ciénegas, Coahuila, were explored, and also the region surrounding Sierra Mojada and the Lago de Coyote, lying partly in Coahuila and partly in Chihuahua. A collection of over 2000 herbarium specimens was made, illustrating fully the distinct floral features of the small mountain ranges that were visited.

A plant collection of nearly 2000 numbers was made by Mr. Robert M. Stewart, of Santa Elena, Coahuila, and presented to Gray Herbarium for study in connection with the Chihuahuan Desert project. This collection is very useful on account of the remote localities in which it was taken and because most of the plants were obtained in the early and late weeks of the summer, periods in which little collecting has been done in any part of northern Mexico.

A collection made by Mr. Lowden Stanford and associates, of the University of

Washington, in the summer of 1941 was placed in Dr. Johnston's hands for determination. This series of 1100 numbers was collected in poorly known hilly and mountainous regions in southern Coahuila, including the Sierra de Jimulco, the Sierra de Parras, and the hills around Fraile, Coahuila and Concepción del Oro, Zacatecas. This collection from the "cross ranges" which traverse the center of the Chihuahuan Desert is of considerable floristic and ecological interest.

Dr. Johnston is now preparing for publication the descriptions of nearly 100 new species that have been detected in the collections made by himself, Mr. Stewart, and Mr. Stanford in the field work of the past 2 years.

Further observations were made by Dr. Johnston on the plants confined to outcrops of gypsum or soils rich in gypsum, and a series of samples for analysis was taken in several localities.

In the summer of 1941 Dr. I. L. Wiggins, accompanied by Dr. Reed C. Rollins, visited central Sonora. The aim of the trip was to reach the very arid plains and hills which lie near the Gulf of California between Guaymas and the mouth of the Río Sonora. Part of the region was visited, but much of it was found impossible of access without more elaborate equipment. So many of the plants previously supposed to be endemic to the peninsula of Baja California have been found in restricted localities between Tiburón Island and Guaymas that this trackless stretch of desert coast continues to have an inviting interest. Dr. Wiggins also visited the foothills east of Hermosillo and made a collection of over 500 plants. During his stay in the field he took the opportunity to give the test of actual use to the keys for determination of plants that have been prepared for the completed parts of his flora of the Sonoran Desert.

ENVIRONMENTAL CONDITIONS

In arid regions the character of the rainfall outweighs other physical conditions in its influence on the local or habitat distribution of plants. It is necessary to consider several aspects of the rainfall other than the annual mean. In fact, this latter datum is only of very general importance.

In a study of the relation of rainfall to vegetation in the Sonoran and Chihuahuan deserts it has been found desirable to make a comprehensive examination of the records for the whole of northern Mexico. Only in this way is it possible to understand the larger storm movements and to know about the rainfall conditions just outside the desert. The regular annual recurrence of storms originating in the Caribbean Sea and the Pacific Ocean is responsible for the seasonal distribution of the desert rainfall. The amounts and distribution of rain just outside the desert represent the minimum requirements for other types of vegetation, and in some cases are indirectly inimical to desert plants. The most arid types of vegetation bordering the Sonoran and Chihuahuan deserts, excepting other desert areas, are the thorn forest of the Pacific coast, the grassland and chaparral of Chihuahua and Coahuila, and the arid bushland of the northeastern coast and the mountains of the central plateau.

From available records it has been possible to determine several special features of rainfall. Use has been made of all sets of data extending from 1920 to 1940 and also the readings for 15 or more years from a few stations in thinly settled areas. Few complete records for more than 20 years are available. Lack of records of daily precipitation over long periods has been a handicap. For the past 5 years the Mexican Meteorological Service has kindly supplied copies of its daily weather map, carrying

daily rainfall readings, which will eventually furnish a basis for more accurate work on rainfall intensity, daily extremes, and duration of drought periods.

Variation in the annual rainfall total is well known to increase as the mean total becomes smaller. In tropical Mexico and just outside the borders of the desert in northern Mexico, the wettest years yield from 1.5 to 3 times the total for the driest years. In the Sonoran Desert there are stations at which the fall in wet years has been from 16 to 329 times that of the driest years.

Rainless periods of more than 1 month are rare outside the desert on the east coast. In the Chihuahuan Desert several stations have had rainless periods of 4 months during the 20 years. In the Sonoran Desert periods of 10 to 18 months without rain have been experienced at five stations. These long periods are particularly characteristic of Baja California and the Gulf coast of Sonora. Their importance to vegetation is obvious. At Mazatlán, Sinaloa, well within the thorn forest region, the longest rainless period was 7 months, an eloquent testimonial to the semiarid character of the thorn forest.

As one crosses northern Mexico from west to east (Ensenada, Baja California to Matamoros, Tamaulipas), the differences in total rainfall are outweighed in importance by the pattern of seasonal distribution. The rainfall of northern Baja California is confined to the winter, that of northern Sonora is biseasonal, that of Chihuahua is mainly in the 4 summer months, that of Coahuila is rather evenly distributed through the last 8 months of the year, and that of northern Tamaulipas (which is outside the desert) is well distributed throughout the year, with early and late summer maxima. These great differences in seasonal distribution are correlated with marked differences in vegetation.

As one crosses Sonora and Sinaloa from north to south, there is found to be a sharp increase of rainfall between Ciudad Obregón, Sonora and Culiacán, Sinaloa, at the transition from desert to thorn forest. Also there is a gradual decrease of winter rainfall between the international boundary and Mazatlán, and an increase of summer rainfall. At Nogales, Sonora, the rain of July, August, and September is 60 per cent of the annual total, whereas at Mazatlán it is 79 per cent. In southern Arizona and northern Sonora a biseasonal rainfall of 8 to 12 inches is found in the desert, but at Culiacán and Mazatlán a nearly uniseasonal rainfall of 24 and 28 inches respectively serves to maintain the thorn forest.

Throughout the southwestern United States and northern Mexico the gradients of altitudinal change in rainfall are controlled by distance from the sea, by prevailing winds, by the steepness of slope of the land masses or mountains that are encountered, and by the summit altitude of the mountains. The influences exerted on vegetation by rainfall are further complicated by temperature conditions, slope exposure, underlying rock and soil, and other conditions. The topographic influences on rainfall are of great importance in the control of the several types of vegetation in northern Mexico. The conditions are such, however, that there is no altitudinal control of the occurrence of desert, which exists from sea level to 7200 feet.

PALEOBOTANY

RALPH W. CHANEY

As has been emphasized in previous reports, the climatic and topographic setting of living plants, readily determinable from a study of modern environments, may be projected back into the past to a time when similar vegetation covered the earth, leaving its record as fossils in the rocks. Interpretation of Tertiary floras, whose members have survived in modified form in the forests of today, provides many details regarding the physical history of North America. During the early years of our study of Tertiary paleobotany in the western United States, the close similarity of certain fossil floras to living forests became apparent. In our first discussions of the Bridge Creek and Mascall floras, relationships to the modern redwood forest, to the border redwood forest, and to deciduous forests in eastern North America and Eurasia were indicated. Subsequently reference has regularly been made to groups of fossil species whose equivalents have survived in modern forests, the

groups being termed the Redwood element, the Deciduous element, and the Asiatic element of the flora involved.

In later years, elements in Tertiary floras have been designated by several workers in western America, but the application of names has not always been consistent. It seems desirable at this time to standardize the use of the terms applied, and to clarify the implications of such usage. In consultation with Drs. Herbert L. Mason, Lincoln Constance, and Daniel I. Axelrod, all of whom have spent much time considering the problem, definitions and a classification have been devised. A fossil flora may be broken down into elements whose living equivalent species are found in association at the present time. An *element* may be defined as a group of fossil plants whose modern related species occupy a major geographic and climatic province.

In all Tertiary floras studied, divergent types of vegetation may be noted which

are assignable to several elements. The five elements commonly designated in Tertiary floras of western North America are:

1. *The West American element* is made up largely of conifers, with broad-leaved evergreens commonly present. The region which their most typical living equivalents now occupy is characterized by temperate climate, with winter rainfall and summer drought, and with a moderate range of temperature.

2. *The East American element* is made up largely of broad-leaved deciduous genera, with conifers of minor importance. The region on the eastern side of North America now occupied by their living equivalents is characterized by temperate climate, with well distributed rainfall of which a considerable amount falls during the summer, and with seasonal extremes of temperature, most trees losing their leaves during the cold season.

3. *The East Asian element* is made up of genera now confined to eastern Asia, and includes also genera occurring in other parts of the world whose species show close resemblance to those now living on the western side of the Pacific. The climatic requirements of the living equivalents of this element are essentially the same as those outlined for the equivalents of the East American element, except that the East Asian element also includes genera which now range into the tropics.

4. *The Southwest American element* is made up largely of microphyllous plants whose living equivalents have their centers of distribution in the mountains of northern Mexico, extending northward into New Mexico and Arizona, and along the coast from Cape San Lucas to central California and into the interior. Seasonal extremes both of temperature and of precipitation characterize these regions, in which the climate is temperate except at the south.

5. *The Caribbean element* is made up mostly of evergreen angiosperms with large, entire-margined, thick leaves. The region occupied by the modern equivalents of Tertiary members of this element, including

southern Mexico and much of Central America, has a subtropical to tropical climate, with high, generally well distributed rainfall and temperatures free from frost.

The Caribbean element in the Tertiary of western North America is best developed in floras of Eocene and Lower Oligocene age. It survived into the Miocene of Washington and Oregon in coastal and other favorable situations, and has been noted with greatly reduced representation in Pliocene floras as far north as central California. The West American element is dominant in Upper Oligocene and Miocene floras of the western United States, continuing into the Pliocene and down to the present at middle latitudes, and in the mountains farther south. The East American and East Asian elements are also abundantly represented in floras of Middle Tertiary age, becoming rare in the Pliocene and disappearing at the close of the epoch. The Southwest American element makes its first well established appearance in the Miocene of southern California, although there is reason to think that it may have been represented in the Florissant flora of Colorado, which MacGinitie believes to be of Oligocene age. It ranged northward into Oregon and Idaho at the close of the Miocene, and was restricted southward during the Pliocene.

A complete enumeration of modern plant climaxes in North America must of course include a grassland unit, which might be termed the Interior American element. Since our classification refers not to modern but to Tertiary vegetation, and since fossil collections from the western United States include no important representatives of the grassland climax, we have not designated an element corresponding to it. The important studies of fossil grasses by Elias may at some future time warrant the inclusion of an Interior American element made up of Tertiary grasses

and forbs. In the same way, it may eventually be desirable to set up a Boreal American element to include Tertiary plants whose modern equivalents are now most characteristic of high North American latitudes. Such plants appear to make up an important part of several older Tertiary floras from the arctic islands, but since they are not well represented in the fossil floras of Oregon and adjacent areas, the Boreal American element is not included in the classification here presented.

From even a cursory reference to the distribution of tree genera in modern forests, it is apparent that there must be some overlapping of the constituents of these elements. The East American and East Asian elements each have distinctive genera; but there are others common to the two which have species so similar that they may equally well be considered as the fossil equivalents of species now living either in eastern America or in eastern Asia. The marked similarity between the vegetation on the east sides of the two continents has been well known since the days of Asa Gray, and is to be expected because of the climatic similarity of the regions. But there are also differences, which are emphasized by the study of forest evolution in the western United States; it therefore seems essential that separate element rank be assigned to these major forest units of the two continents. There are likewise close relationships between the East and West American elements; it is not always possible to determine whether a fossil species of sycamore, *Platanus dissecta* Lesquereux, has as its modern equivalent the eastern species, *P. occidentalis* Linnaeus, or the western species, *P. racemosa* Nuttall; one of the most common fossil species of black oak, *Quercus pseudo-lyrata* Lesquereux, seems almost equally related to living oaks on both sides of the continent. Such dual

representation of fossil species is to be expected in a classification as general as ours, and serves to emphasize the common origin of forests now widely separated, but intermingled in the generalized vegetation of the Tertiary period in the western United States.

A further comment seems necessary to clarify our attitude toward comparisons between fossil and modern plants. All our lists of equivalent living species are at best a tentative expression of opinion regarding the modern affinities of fossil species. These suggested relationships are based largely on leaf similarities, with the supporting evidence of fruits or seeds also available in some cases. Such comparisons are highly suggestive, and are made whenever the fossil specimens are sufficiently well preserved; but they are not to be considered as final evidence of phylogenetic relationships. Whether a fossil oak finds its nearest living descendant in the forests of North America or in those of eastern Asia, the fact that similar living species may be noted on both continents is highly significant in any consideration of the Tertiary history of vegetation in the northern hemisphere. Such relationships also make possible a more natural interpretation of the origins of modern forests.

Each of the elements designated in Tertiary floras may be further subdivided into *components* which represent their major floristic units. Component names are assigned to emphasize dominant plants, secondary topographic features, or climatic zones. The components most commonly recognized in discussing the Tertiary history of the West American element are the Redwood, the Border-redwood, the North-coast coniferous, the Sierra-Cascade, and the Rocky Mountain. Usage will vary somewhat until the significance of these components in Tertiary vegetation becomes better understood. The Border-

redwood component may represent an ecotone between the Redwood component and two components of the Southwest American element, the Oak woodland and the Chaparral. Locally the modern forest equivalents of the North-coast coniferous and the Sierra-Cascade components grade into one another, and their place as distinct units in the forests of the Tertiary may in some cases be open to question.

A natural division of the East American element would recognize the Beech-maple, the Oak-hickory, the Coastal pine, and the Swamp cypress-tupelo components. All these except the Coastal pine are well represented in the Middle Tertiary floras of the western United States. It is possible that additional components may be designated as current studies of the Mascall and Bridge Creek floras of Oregon are continued.

The East Asian element is subdivided, largely on the basis of climatic and topographic units, into Northern temperate highland, Northern temperate lowland, Southern temperate highland, Southern subtropical lowland, and Southern tropical lowland components. It seems probable that future field studies in Asia will make possible floristic and geographic names corresponding to those assigned to the components of the East American element, names which will carry a more significant connotation.

The Southwest American element is divisible into the above-mentioned Oak woodland and Chaparral components, and also into Conifer woodland, Closed-cone pine, and Coastal sage. The Oak woodland component, occurring under a wide range of topographic and climatic conditions, represents a more diverse floral unit than the other components of the Southwest American element; but it does not appear to indicate a wider range of com-

position than do certain components in the East American and West American elements.

The subdivisions of the Caribbean element, as in the case of the East Asian, are tentative as here presented. They include the Warm-temperate highland, Subtropical lowland, and Tropical lowland components. More definite component names will be assigned in future discussions of Eocene floras, in which the Caribbean element is largely represented.

It should be emphasized that element and component names are applied to groups of fossil plants to emphasize their resemblance to modern vegetation, and that they do not necessarily coincide with the names or units involved in the study of living plants. In cases where groups of fossil plants have living equivalents occupying well defined geographic or climatic provinces and subprovinces, it is convenient to designate them in terms of these living equivalents and their habitats. Our element and component names indicate the *present* distribution of surviving equivalents of Tertiary species, not their past distribution; there is no inherent basis for assuming that a Miocene oak assigned to the East American element was living in the eastern United States during that epoch; only its discovery there in Miocene rocks would indicate that its range at that time coincided with its present distribution. Further, there is not the slightest implication that the provinces covered by element names represent the centers of dispersal of the plants involved. The modern occurrence of *Cercidiphyllum* is no more an indication that it had its origin in China than is the presence of *Sequoia* in California evidence that it is a native son. Centers of origin and modern range of species may in some cases coincide; but when there is a wide time discrepancy between the living tree and its

fossil equivalent, there are likely also to be wide discrepancies between their Tertiary and Recent distribution, representing the distances covered in the course of forest migrations through geologic time.

One further consideration warrants brief comment at this point. Many floras, especially those of Middle Tertiary age, include several elements representing forests now widely separated in regions with diversified climates. We conclude that such vegetation was of a more generalized type than are most living forests. Physical changes toward the later part of the Tertiary period brought diversified topography and climate, producing the geographic and climatic provinces which we recognize, each with its distinctive forest. Differentiation of the generalized vegetation of the past into modern floristic units may best be expressed by the recognition of diverse ingredients in Tertiary forests. Such ingredients, which we term elements and components, represent groups of trees whose varying response to earth change has resulted in their restriction to the modern regions best suited to their requirements. A survey of modern forest environments and a comparison of their vegetation with that of the past provides the most adequate basis for our understanding of continental history, since it makes possible a reconstruction of the topographic and climatic setting of Tertiary forests.

During the past year a significant comparison has been made between the swamp cypress forest of southern Indiana and the Mascall flora from the Miocene of Oregon. Unlike the *Taxodium* forest living farther south, the swamp cypress near

the northern limits of its range is closely associated with black oak, hickory, and maple. These trees grow on the borders of the swamp, and their leaves may be found mingled with those of the cypress in sediments now accumulating. Similar accumulation of leaves in the lake deposits of Oregon's past has given us a fossil assemblage with essentially the same composition, and a closely similar environment is indicated. Unlike the somewhat older Bridge Creek flora, in which *Sequoia* is the dominant conifer, the Mascall assemblage suggests the presence of swamps and lakes during later Miocene time. Known facts regarding the geologic history of the John Day Basin during this stage are consistent with such a topographic picture. Immense amounts of volcanic ash were accumulating along the courses of streams, which were locally overloaded with these sediments, or dammed by lava flows. By contrast, the Bridge Creek shales laid down at the close of the Oligocene and the beginning of the Miocene seem to represent valley accumulation under more normal conditions of gradation. The modern occurrence of the redwood is confined to well drained valleys, and that of the swamp cypress to those which are poorly drained. The difference between the Bridge Creek and Mascall floras may be due more to topographic than to climatic changes during Middle Tertiary time.

The studies of Dr. Chaney's associates, Daniel I. Axelrod, Erling Dorf, and Harry D. MacGinitie, have continued along the lines outlined in recent reports. Their publications are listed in the bibliography.

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DEPARTMENT OF EMBRYOLOGY

Baltimore, Maryland

GEORGE W. CORNER, *Director*

The program of the Department of Embryology has followed, as fully as present conditions permit, the plans set forth in last year's report. The collection of embryos has been increased by many acquisitions, notably a number of very early human embryos which are described below. The publication of several papers and a comprehensive volume on the embryology of the rhesus monkey marks the completion of the general exploration of that subject which has been under way for some years, although many special problems remain to be studied. The work in experimental embryology, using the remarkable advantages afforded by the opossum, in which the young, while still in embryonic condition, are accessible in the brood pouch, proceeds successfully and is yielding results which will appear in the next report. Studies, by physical methods, of placental function and of the measurement of the sex-gland hormones in the blood and tissues have been interrupted by the transfer of the investigators concerned to duties directly connected with war service, but the work on the

placenta had fortunately gone so far that it has been possible to set down a considerable body of results and to draw instructive general conclusions. A general investigation of the mammary gland of the monkey and its reaction to the sex-gland hormones has reached a similar stage. Details of these and other projects will be found in the following pages. Although at the present writing it is difficult to foresee the course of events, even within the relatively sheltered walls of a research laboratory of embryology, it appears that we shall be able to preserve and exploit our unique collections and to keep up a significant part of the investigative program, while doing everything possible to share in the national effort.

During the year the facilities of the Department were made available to a number of scientific visitors, including Dr. Joseph Gillman, of the University of the Witwatersrand; Dr. Emil Witschi, of the University of Iowa; and Dr. T. L. Terry, of the Massachusetts Eye and Ear Infirmary.

EMBRYOLOGY

EARLY HUMAN EMBRYOS OF THE PRE-VILLOUS STAGE

This year the Department is again able to report notable progress in the study of early stages of human development. In 1939 (Year Book No. 38) Dr. Streeter mentioned the acquisition of two new human embryos, of about the 11th and 12th days, which had been obtained by Drs. A. T. Hertig and J. C. Rock, of Boston.

These two complete and perfect specimens, together with the previously known but incomplete Miller ovum, formed a group at what was then the earliest known stage of human development, so that an important period which had been known only hypothetically (so far as the human species is concerned) has now become known by actual observation.

Some information about these two valu-

able embryos was made public by Dr. Hertig and Dr. Streeter in lectures and demonstrations to scientific societies; photographs and reconstructions illustrating them were exhibited at the 1939 Annual Exhibition of the Carnegie Institution, and photographs have even been made available for use in one or two textbooks. Thus these embryos have already to some slight degree contributed to professional knowledge. Drs. Hertig and Rock have now completed their detailed study, and full descriptions of both embryos appear in the current volume (XXIX) of the Carnegie "Contributions to Embryology." It is now a pleasure to announce that these indefatigable investigators, whose work has been aided by a grant from the Carnegie Corporation of New York, have continued with success their painstaking search for early human embryos. Up to the present they have obtained and deposited in our collection no less than 52 specimens, among which are 12 embryos of the 2d and early 3d weeks. Of these, 7 are to all appearances normal and 5 show various abnormalities. It need hardly be added that the earliest disturbances and abnormalities of human development are quite as important as the normal stages.

During the past year Drs. Hertig and Rock have obtained two embryos definitely earlier than any previously known, one of them believed to be $9\frac{1}{2}$ days old (Carnegie no. 8004) and the other $7\frac{1}{2}$ (Carnegie no. 8020). These, like all the others, have been successfully cut into sections, stained, and mounted by Dr. Heuser, Mr. Heard, and Miss Caspari, and fully photographed by Mr. Reather.

This special collection of human embryos constitutes an inestimable scientific treasure, rich in precise information about the development of the embryo and especially about the first stages of its attach-

ment to the mother, before the development of placental villi and of the yolk sac.

Descriptions of the first two of the Hertig-Rock embryos, nos. 7699 and 7700 of the Carnegie Collection, have been published in full, as mentioned above. Their nature will be made clear to those readers of this report who are not biologists by the accompanying diagrams (figs. 1, 2). Both embryos are earlier than the stage represented by the first (left-hand) sketch in figure 1. No. 7699 is believed to be 11 days old, no. 7700 to be 12 days old. They are both very small. Either of them would quite easily pass through the open space of the small letter "o" of the type in which this report is printed. As will be seen in figure 2, both of them have barely finished growing into the lining of the uterus, being separated from its cavity by only a thin layer of tissue. At this stage the embryo itself is very simple, consisting of a disk of ectoderm with a disk of endoderm applied to its ventral side. In the case of the younger embryo this bilaminar embryonic disk is roughly circular, so that it is not yet possible to determine with certainty the direction of the future long axis of the body it is destined to form. Its diameter is 0.138 mm.; that is to say, 7 such embryonic disks, if arranged in one layer on the printer's period at the end of this sentence, would not completely cover it. In the older embryo this "disk" has grown a little longer and narrower.

Over the back, so to speak, of the embryonic area, in each of these embryos, the amniotic cavity is already visible. Ventral to the endoderm is a cavity in the region where the yolk sac will become well defined a day or two later. This cavity is walled by the delicate exocoelomic membrane (Heuser's membrane). Just how the first cells of the endoderm are related to this membrane, and how the membrane, in

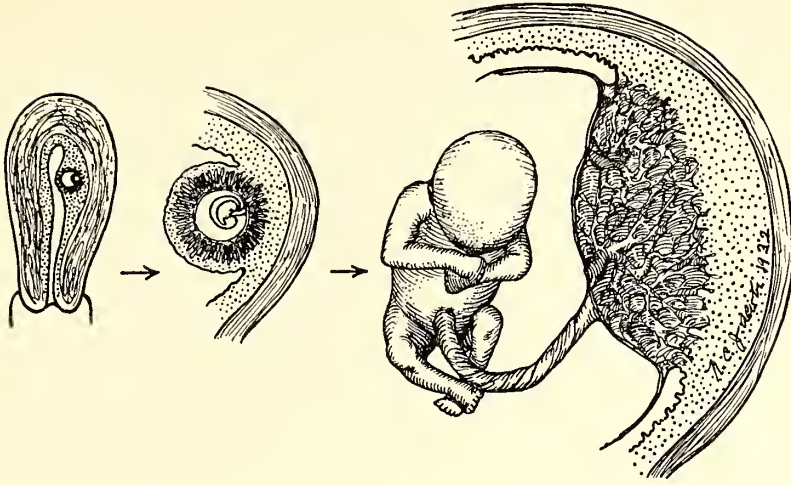


FIG. 1. Diagram showing location and development of the human embryo. The left-hand figure represents a stage a little later than the Hertig-Rock embryos mentioned in the text (embryo is drawn disproportionately large with respect to the uterus).

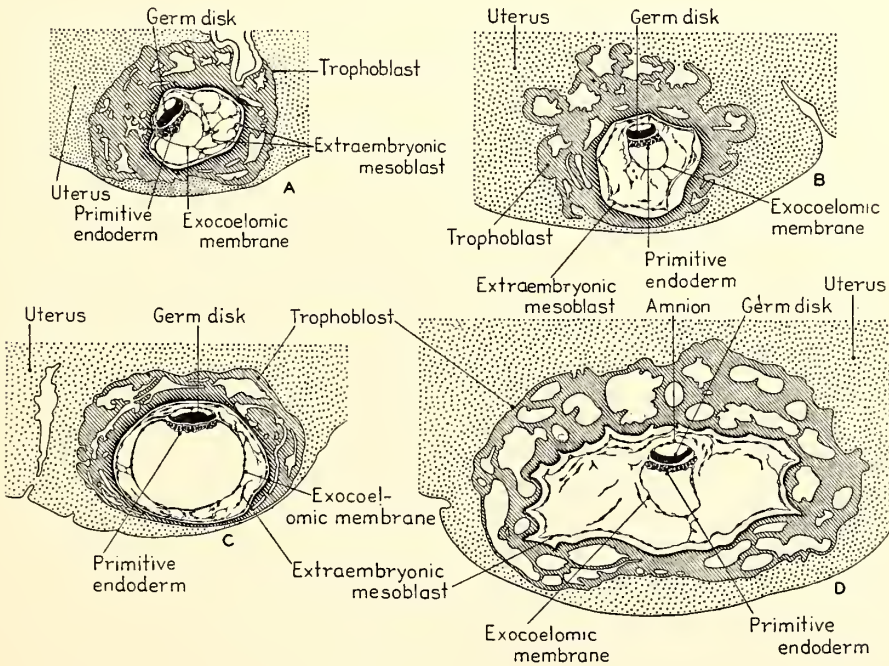


FIG. 2. A and C are diagrams of the Hertig-Rock embryos, Carnegie nos. 7699 and 7700 respectively. B and D show two previously known but slightly more advanced embryos, namely the Miller ovum as reconstructed by Streeter, and the Werner (Stieve) embryo.

turn, is related to the yolk sac, are questions still eagerly discussed by those who have studied these early embryos, but destined no doubt to be cleared up in subsequent publications.

The cavity in which each embryo lies, relic of the original blastocyst cavity, is surrounded by the trophoblast or outer cell layers, whose function is to establish relations with the maternal blood circulation. Already in these early embryos the trophoblast has differentiated into an inner cytotrophoblast and an outer syncytiotrophoblast. The latter, as indicated in figure 2 (and of course fully illustrated in the article by Hertig and Rock), has begun to form a series of cavities, the trophoblastic lacunae. Into these spaces the maternal blood capillaries early begin to open, so that some of them, even in the younger specimen, contain maternal blood. The inner layer, the cytotrophoblast, is in the older specimen beginning to form cell groups pushing outward into the syncytiotrophoblast. In the cores of these knobs (which are the first beginnings of the placental villi) the earliest signs of the embryonic blood vessels are seen as a primitive angioblast. The rudiments of the uteroplacental circulation are thus laid down. There is no necrosis of maternal tissues. Early decidual cells are forming in the stroma of the endometrium adjacent to the embryonic trophoblast.

In the case of the younger embryo, 730 cc. of the maternal urine collected during the 2 days preceding operation, when concentrated and injected into a rat, produced ovarian changes characteristic of the Zondek-Aschheim test for pregnancy, a truly remarkable finding in view of the early stage of pregnancy.

TWO HUMAN EMBRYOS IN THE PRESOMITE STAGE

Dr. Joseph Krafka, Jr., of the University of Georgia, contributes to volume XXIX of

the "Contributions to Embryology" a description of a human embryo of the presomite stage. This is the Torpin ovum, so called after Dr. Richard Torpin, of the Department of Obstetrics and Gynecology of the University of Georgia, who obtained it at operation. Its age is estimated to be 13 days. The specimen is complete and in a good state of preservation. It is particularly interesting with regard to the blood vessels at the site of implantation, since it well shows the early development of the venous sinusoids characteristic of this stage of attachment. Dr. Krafka has given not only a clear description of the specimen, but also a good deal of interpretative analysis which must be taken into consideration when a general account of human embryos of this period comes to be written.

Dr. H. O. Jones and Dr. John I. Brewer, of the University of Chicago, present in the same volume an account of an embryo in the primitive-streak stage, estimated to be 18½ days old. It is designated as the Jones-Brewer ovum I (not to be confused with the Edwards-Jones-Brewer embryo, *Contributions to Embryology*, vol. XXVII). It shows the earliest stage of the head process thus far described in the human embryo. The first signs of the neurenteric canal appear as three small spaces within the primitive knot (Hensen's node). The specimen is therefore especially instructive for study of the so-called gastrulation of the human embryo.

EMBRYOLOGY OF THE RHESUS MONKEY

For more than twenty years this laboratory has been investigating the embryology of the rhesus monkey. It is hardly necessary to explain the value of such a study of the development of one of the infra-human primates, carried on in parallel with that of the human. The experience thus obtained and the resulting large collection of monkey embryos, obtained ex-

perimentally and therefore properly timed and preserved, has served to guide the study of very early human embryos such as are discussed above. Knowledge of the physiology of reproduction in the monkey, gained in the course of this work, has contributed greatly to our understanding of menstrual phenomena and ovarian function in mankind as well as in the monkey itself. Moreover, as will be emphasized a little later, this study of the monkey, revealing for the first time the earliest stages of primate development, contributes to embryological thinking in general.

In 1921, the embryology of the monkey was quite unknown and the general physiology of reproduction in this animal was not understood. In 1942 the rhesus monkey is in these respects one of the best-known mammals. The work on this species has been led in this laboratory by Drs. G. L. Streeter, C. H. Heuser, and C. G. Hartman, whose part in it was referred to in last year's report (Year Book No. 40). These workers have been in constant touch with colleagues studying monkeys in other laboratories, including especially Drs. G. B. Wislocki, of Harvard University; G. W. Bartelmez, of the University of Chicago; J. B. Markee, of Stanford University; and G. W. Corner while he was at the University of Rochester. All these investigators have added to the subject through articles in the "Contributions to Embryology" as well as in other journals.

It has been possible to publish this year three papers which describe the development of the rhesus monkey from the egg in the ovary until birth. Drs. C. G. Hartman and G. W. Corner describe six ovarian eggs, two of which were undergoing the first maturation division. In the monkey, as in the majority of mammals, the first maturation division occurs within the follicle just preceding its rupture. The egg therefore leaves the ovary with the

polar body formed and the second polar division in progress. Drs. W. H. Lewis and C. G. Hartman take up the story at this point with the description of eight eggs recovered from the oviduct, two of which were in the 2-cell stage and six were non-fertile. To these may be added four eggs previously described by the same authors, from the 2-cell to the 16-cell stage.

The long campaign of investigation of monkey embryology is brought to a climax in this volume by an extensive monograph on development of the macaque embryo by Drs. C. H. Heuser and G. L. Streeter. This work is first of all a photographic atlas on the subject. Its 33 plates, comprising 259 separate photographs, illustrate every stage of development from the early blastocyst of 8 days to the fetus of 57 days. The article includes a systematic list of 123 specimens used in the work, which are now available for reference in the Carnegie Embryological Laboratory. The accompanying text covers especially the period from the early blastocyst to the stage of somite formation; that is to say, the period of development least well known in the human species and that in which all the outstanding problems of primate and even of general mammalian embryology are centered.

This account is remarkable for several reasons. Well aware of the novelty of their material, which as they say has turned an entire new page in primate embryology, the authors have described it in a fresh and unconventional way. They have emphasized the idea that the embryo is not merely a morphological abstraction. It is indeed at every moment of its life a growing organism with constituent parts and tissues which have their functions to perform. Turning away from the diagrammatic interpretation and homologizing of earlier writers, the authors place little emphasis upon morphological theory, and

set aside, at least temporarily, phylogenetic comparisons and the time-honored search for evidence of recapitulation. The resulting discussion is often therefore very stimulating. For example, the authors see the embryo as a continuous center of undifferentiated formative tissue surrounded by an increasing body of specialized tissue. At first, when the ovum is a single cell, it is itself the undifferentiated mass. Then, as segregation proceeds and the wall of the blastocyst is formed, the inner cell mass continues to contain unoriented formative cells, which give rise to the germ disk. As the germ disk in turn differentiates, the primitive knot and probably the primitive streak remain as the undifferentiated center, which gives rise to specialized tissues as it gradually retreats tailward until all the undifferentiated tissue is used up.

Likewise their description of the implantation of the embryo and the earliest steps in the development of the placental circulation is exceptionally complete and clear. It aids greatly in explaining the conditions in man, known from an incomplete series of isolated specimens.

The correlation of age and form in the monkey furnishes dependable criteria of age in the human embryo. The growth curve of the macaque embryo, as well as the external form, is essentially the same as for human embryos during the first six weeks. The diverging characteristics appear later in development.

On other points there will be much discussion. Any reader who follows, for example, the account of the origin of the yolk sac will see that the two authors hold different views, and he may find himself trying to make up his own homologies as he studies the photographic evidence presented. Some readers may feel that the emphasis on the immediate functional value of the embryonic organs leaves aside important considerations regarding the

past and future history of these same organs. The authors have certainly rescued such structures as the early trophoblastic wall and the primitive streak from being merely tracings on a phylogenetic diagram, making us see them as living and functioning tissue; it will be sufficient, on the other hand, to mention the allantoic rudiment as an example of structures that can only be understood in the light of their homologies. Drs. Heuser and Streeter promise us, however, later papers in which their findings are to be related to the more familiar interpretation and terminologies.

In his Hatfield Lecture at the College of Physicians of Philadelphia, 1941, Dr. Streeter has given a helpful summary of his concept of embryogenesis in monkey and man, based largely on the monograph just discussed.

In order to make the Department's work on the embryology of the rhesus monkey readily available to laboratory workers, the Carnegie Institution has reissued in one volume these three papers from volume XXIX together with a paper on the growth of the monkey by Dr. A. H. Schultz, from volume XXVI, and one by Drs. G. B. Wislocki and G. L. Streeter on the placentation of the rhesus macaque, from volume XXVII. This special volume, which is Embryology Reprint Volume I, entitled *Embryology of the rhesus monkey (Macaca mulatta)*, forms an almost complete embryological treatise on this species. Its usefulness has been appreciated by the investigators to whom copies have been distributed.

ORIGIN OF THE RETE APPARATUS

In Year Book No. 40 a brief report appeared of the finding of Dr. R. K. Burns, Jr., that in opossums the ostium of the Müllerian duct and the rete canals of the gonad are members of a series of primitive nephrostomes. In an article in *Science* (see

bibliography) these conclusions have now been published in detail, with an explanatory diagram.

Dr. Burns' investigation of the effect of the sex-gland hormones on the embryonic reproductive system of the opossum, men-

tioned in the last Year Book, has progressed notably. Some of the results were presented at the 1942 meeting of the American Association of Anatomists and at the June 1942 session of the Cold Spring Harbor Symposium.

PHYSICOCHEMICAL STUDIES

OXYGEN CONSUMPTION OF THE EMBRYONIC BRAIN

In the last report (Year Book No. 40) mention was made of the increasing application of physics and chemistry to embryology, and of our hope that such work may be carried forward in our laboratory. A good example of the kind of beginnings that are being made in this field is a paper by Drs. Josefa B. Flexner, Louis B. Flexner, and William L. Straus, Jr., on oxygen consumption and the oxidation mechanism in the cortex of the fetal brain, as related to the development of histological structure. Using brain tissue from pig fetuses, readily available at the slaughterhouse, the investigators have applied the standard techniques for measuring oxygen consumption and the activity of the respiratory enzymes. To cite their summary: Two critical periods, the first about halfway and the second about four-fifths of the way through gestation, have been found in the morphological differentiation of the fetal cerebral cortex. Both are characterized by rapid increase in size of the nerve cells, by changes in their form, and by abrupt changes in the quantity or pattern of the Nissl substance. During the first period, cytochrome-cytochrome oxidase activity shows a distinct rise, and during the second period, the Q_{O_2} increases to the level characteristic of the adult. Variations in cytochrome-cytochrome oxidase activity at different parts of the gestation period are not reflected in corresponding variations

of Q_{O_2} . Cytochrome oxidase activity has been found constant at all stages of fetal development investigated. The increase in cytochrome-cytochrome oxidase activity with increasing fetal age consequently appears due to an increase in concentration of cytochrome c. The $Q_{O_2}^{CN}$ of fetal and adult cortex is about 1.

PHYSIOLOGY OF THE PLACENTA

In Year Books Nos. 39 and 40 mention was made of the program of research on the physiology of the placenta as an organ of transfer, under the direction of Dr. Louis B. Flexner, aided by Drs. Alfred Gellhorn and Herbert A. Pohl. Rapid progress has been made in the work, but it has necessarily been discontinued in 1942, because of Dr. Flexner's absence on duty with the National Research Council and the diversion of his colleagues to wartime projects. For this reason the present seems an appropriate time to summarize the results which have been achieved to date. Readers of this report who desire more details than can be given here will find a review by Flexner and Gellhorn in the paper cited in the bibliography. A few passages and a table and diagram from this article are incorporated in the following statement.

The first effort has been to determine the rate of transfer of relatively simple substances from mother to fetus through the placentas of various animals. For this purpose radioactive sodium has been

chosen as the beginning tracer material, because it is easily prepared by the cyclotron or electrostatic-pressure generator, its behavior in the body is not complex, and it is one of the physiologically important chemical building stones of the organism. The radioactive salt was prepared with the high-voltage generator of the Department of Terrestrial Magnetism of the Carnegie Institution, and with the cyclotron of the Department of Physics of Harvard University. A solution of known potency is injected into the blood vessels of a pregnant animal, and after a suitable time the fetuses are recovered by autopsy or Caesarean section. The amount of radioactive sodium which has passed from the maternal blood across the placenta to the fetus is determined by measuring the amount of radioactivity in the ashed remains of the fetuses.

Before planning the series of experiments, the investigators asked themselves the following questions, as expressed in their review:

Does the permeability of the placenta vary with the period of gestation? If the answer be positive, what are the underlying causes for the variation? Are there differences in permeability among the several morphologic types of placenta? Is the quantity of substance transferred across the placenta related to the rate at which the fetus is growing? Does the placenta act as an inert membrane or filter placed between the maternal and fetal circulations, or does it modify the transmission of substances by contributing energy to the process and so acting as an organ of secretion? How is the failure of a substance to pass the placenta related to its physical and chemical characteristics? What effects do pathologic processes have upon placental transmission and so upon the nutrition of the fetus?

If the placentas of all mammals were

alike in structure and function, the investigation would be relatively simple. The fact is, however, that placentas differ greatly in the degree of intimacy with which the maternal and fetal blood streams approach each other. Essentially, the placenta consists of a special area of the uterine lining, covered by a pavement of epithelial cells, supported on a layer of connective tissue, and underlain by a sub-surface bed of blood vessels. Against this lies an area of fetal membranes, also consisting basically of a layer of epithelial cells supported by connective tissue and underlain by blood vessels. In the domestic pig, for example, this arrangement exists in full, and therefore a molecule of sodium chloride going from the blood of the mother to that of the fetus, or a molecule of carbon dioxide going out, has to pass through all the tissues mentioned above as through a filter. It must traverse six layers, namely, the maternal blood-vessel wall (endothelium), connective tissue, and epithelium, and the fetal epithelium, connective tissue, and endothelial blood-vessel wall.

In other species the maternal and fetal layers of the placenta are much more manifolded and interlocked with each other than in the pig, and in various species the fetal epithelium and fetal connective tissue are lost. Thus the thickness and complexity of the barrier between the two blood circulations vary considerably in different orders of mammals. There are in general four classes of placenta, as indicated in table 1 and in the diagram, figure 3, based on Grosser's classification.

The investigators studied, as is noted in the table, one species in each of the first of these placental groups and three with hemochorial placentas.

It must be understood that the above-cited analysis and classification is not rigid. There are variations within each group,

and in individual species changes occur during the course of pregnancy. In the sow, for example, the epithelial layers become thinner as pregnancy advances. In the cat, guinea pig, and rabbit even the fetal (chorionic) epithelium largely disappears, bringing the maternal blood into contact with fetal blood vessels, and thus

and fetal circulations, the greater the rate of transfer. The relative figures, expressing the amount of Na in milligrams transferred across a unit weight of placenta per hour, at a comparable stage of late pregnancy, are: sow, 0.026; goat, 0.41; cat, 0.69; guinea pig, 6.1; rabbit, 6.8; rat, 8.3. It is very remarkable that such differences

TABLE 1
CELLULAR LAYERS BETWEEN MATERNAL AND FETAL CIRCULATION
(GROSSER'S CLASSIFICATION OF PLACENTAS)

TYPE OF PLACENTA	MATERNAL			FETAL			EXAMPLES
	Endothe- lium	Conne- ctive tissue	Epithe- lium	Epithe- lium	Conne- ctive tissue	Endothe- lium	
Epitheliochorial . . .	+	+	+	+	+	+	Sow
Syndesmochorial . . .	+	+	—	+	+	+	Goat, sheep, cow
Endotheliochorial . .	+	—	—	+	+	+	Cat
Hemochorial	—	—	—	+	+	+	Guinea pig, rat, rabbit, man

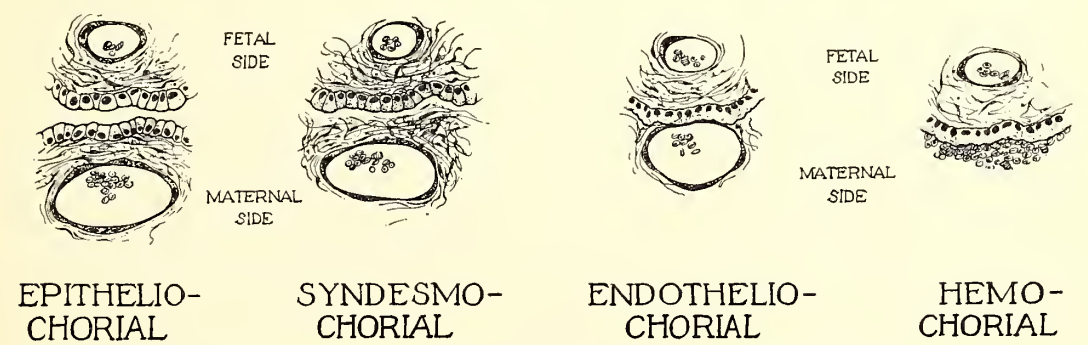


FIG. 3. Diagrams indicating the number and kind of tissue layers interposed between maternal and fetal circulations in each of the four placental types. (From *American Journal of Obstetrics and Gynecology*, by courtesy of C. V. Mosby Company.)

reducing the barrier between the two blood streams, in places at least, to an exceedingly thin layer.
Flexner, Gellhorn, and Pohl found in the first place that the rate of transfer of sodium across unit weights of the four types of placenta varies according to the morphological structure. The smaller the number of tissue layers placed between maternal

should exist between animals whose normal body temperature, pulse rate, and basal metabolism differ by no such great degrees; but the fact is that among mammals the reproductive system is more varied than any other.
In all six species there is a decided increase in the rate of transfer per unit weight of placenta as pregnancy advances.

The reasons for this are not fully understood.

The investigators next sought to know whether there is any relation between the rate of growth of the fetus and the supply of sodium received. The answer to this question can be obtained by comparing the supply of sodium to a gram of fetus per unit time with the rate at which that gram of fetus reproduces itself. The first of these quantities is found by simply dividing the total sodium transferred to the fetus per hour by the fetal weight. The second quantity is the relative growth rate of the fetus and is obtained from data relating fetal weight to gestation age. If the placenta is nicely adapted to the needs of the fetus, one would expect a large amount of sodium to be transferred per gram fetus when the relative growth rate is high, since sodium is an integral part of each unit mass of tissue, and a lower transfer rate per gram fetus when the relative growth rate is low. It was found that in all the six species studied there is a close relation between the rate of transfer per gram of fetus at any given stage of pregnancy and the rate at which the fetus is growing at that time. When the fetus is small but growing rapidly, the rate of transfer of sodium is high; as it grows older and its relative growth rate drops,

the supply of sodium per unit weight of fetus is commensurately low. There seems to be some mechanism underlying placental function by which the rate of supply of substances to the fetus is proportioned to its needs as a growing organism.

A further important deduction concerns the safety factor, i.e., the ratio between the amount of sodium chloride transferred to the fetus and the amount retained by it for use in its life processes and growth. When this ratio is calculated from the observed data, it turns out that the margin of safety is large in all the species studied except the sow. The amount of sodium salt transferred is 25 to 50 times the amount retained by the fetus. In the sow, however, the safety factor is much lower, being only 3.5 at the 16th week of gestation.

This interesting work has recently been extended to the rhesus monkey, and it has also been possible to make observations on human pregnancy by cooperation of the Department of Obstetrics of the Johns Hopkins Medical School. In these later experiments "heavy water" (deuterium oxide) has been used as tracer substance as well as radioactive sodium. The final papers of the series are now in press and will be reported upon next year.

THE REPRODUCTIVE ORGANS AND THEIR HORMONES

PROGESTERONE

The rapid advance in knowledge of the reproductive hormones makes it necessary to review the subject frequently for the benefit of physicians and of investigators in collateral fields. In 1942 the American Medical Association brought out a revised edition of its handbook *Glandular physiology and therapy*. This contains a chapter contributed from our laboratory by

Dr. Corner, which gives a summary of current knowledge about the corpus luteum hormone, progesterone, with especial reference to its use in medical practice.

HORMONE DETERMINATION BY ULTRAVIOLET SPECTROPHOTOMETRY

One of the most serious needs in the study of the sex-gland hormones is for more sensitive methods of detecting the

hormones in the tissues and in body fluids such as the blood and urine. Since the steroid substances have more or less characteristic absorption spectra, spectrophotometric methods are beginning to be tried. Dr. S. R. M. Reynolds, who joined the Department's staff in 1941, spent most of the year in familiarizing himself with the technique of ultraviolet spectroscopy and in planning for apparatus to be assembled in his laboratory. Meanwhile, with the cordial help of the Department of Physics of the Johns Hopkins University and with the collaboration of Dr. Nathan Ginsburg, Dr. Reynolds made a very hopeful beginning on the microdetermination of progesterone. A preliminary account of this work was given before one of the scientific societies in the spring of 1942. A full account is in press and will be reported next year. The work has had to be put aside for the duration of the war, since Dr. Reynolds has been commissioned in the Army Air Force and called to duty at the School of Aviation Medicine, Randolph Field, Texas.

Drs. Carl G. Hartman and Harold Speert have investigated the effect of progesterone on castrated monkeys without previous treatment with estrogenic hormone. Under natural conditions in the body, any female animal in whose ovary a Graafian follicle ripens, sheds its egg, and becomes a corpus luteum will of course already have been under the influence of the general ovarian (estrogenic) hormone. The question thus arises whether progesterone can exert its characteristic effects at all if the uterus, vagina, and mammary glands are deprived of the estrogenic effect by long-standing castration. In general, experiments on lower mammals have shown that progesterone can be made effective in castrate animals by giving it in large dosage. The situation in monkeys

has not been clear. Hartman and Speert gave 5 to 20 mg. of crystalline progesterone daily, for periods ranging from 20 to 32 days, to monkeys castrated respectively 37 days, 50 days, 8½ months, and 4 years.

The hormone produced effects which were in part like those of progesterone following estrogens, and in part like those of estrogens given directly. Reddening of the sex skin, for example, an effect which would have been produced in these monkeys by very small doses of estrone, was produced by progesterone if given in the large dose of 20 mg. daily. Growth of uterus and vagina, and vaginal cornification (all characteristic effects of estrogen) resulted from the treatment. Hormone-deprivation bleeding (experimental menstruation) followed discontinuance of treatment, just as it follows discontinuance of estrogen alone or of the estrogen-progesterone sequence. Development of the mammary gland, with lobular proliferation of the acini, occurred. The authors conclude that the specificity of action of the steroidal hormones is less than has heretofore been supposed.

ESTROGENIC HORMONES

Dr. Hartman, with Dr. C. F. Geschickter, of Baltimore, has been treating rhesus monkeys with very large doses of estrogenic hormones over long periods of time. The chief results of these experiments, which were undertaken to study the relation of the ovarian hormones to cancer and other tumors in the monkey, will be reported later. Meanwhile certain collateral results have been described from time to time. Drs. R. Tyslowitz and Hartman have followed the blood-cell count, reticulocyte count, and hemoglobin level in some of these animals. No significant changes were found, nor anything to indicate a toxic effect of the large doses of estrogens.

Dr. Hartman and Dr. Walter Fleischmann, of the Department of Pediatrics of the Johns Hopkins Medical School, have studied the amounts of cholesterol in the blood serum of rhesus monkeys. The matter is of interest because of the similarity in molecular structure between the long-known steroidal substance cholesterol, which is a plentiful constituent of the animal body, and the sex-gland hormones. At present the biological chemists do not know whether there is any functional relationship between these two groups of steroids. Hartman and Fleischmann found an average blood-serum cholesterol level of 120 mg. per cent in normal females at various times of the menstrual cycle, 110 mg. per cent in the first half of pregnancy, and 80 mg. per cent in the latter half of pregnancy. In 7 of the female monkeys mentioned above, which had received very intensive treatment with estrogenic hormones, the serum cholesterol was high, averaging 151 mg. per cent.

Dr. Thomas R. Forbes, of the Department of Anatomy of the Johns Hopkins Medical School, published during the year a full report of his experiments on the absorption of pellets of crystalline hormones. A summary of this work was given in Year Book No. 40.

Several years ago French investigators reported that the administration of one of the estrogenic hormones to rabbits caused, in certain cases, a change in hair

color and loss of hair in symmetrical areas. In guinea pigs and also in human beings treatment with various estrogenic and androgenic hormones had sometimes been followed by changes in skin pigmentation. In his rats which received pellets of ovarian steroid hormones, Dr. Forbes had an opportunity to make similar observations. In albino rats he noticed partial pigmentation of the fur, and in a strain of dark gray-brown rats he observed alopecia (loss of hair). These results followed implantation of pellets of a large series of estrogenic hormones (of both the naturally occurring and the synthetic types) and their esters. Of the androgenic hormones, androsterone was active in this respect but not testosterone dipropionate.

REPRODUCTION IN THE MUSKRAT

In connection with the Fish and Wildlife Service of the U. S. Department of the Interior, Dr. Forbes has sought to determine the breeding season of the muskrat. Five hundred and sixty-two animals of both sexes were trapped in Maryland. Sections of the testes and ovaries indicate that in the males spermatogenesis begins about the middle of December and continues until the following October. In the ovaries of the females corpora lutea appeared late in February, and similar evidence of ovulation was found until the end of October.

SEX EDUCATION

Our Department is primarily devoted to investigation of fundamental problems, and most of our work is not expected to find immediate application to human welfare. Dealing as we do, however, with embryology and the physiology of reproduction, we are inevitably brought into contact with the human side of these

subjects and see them in the light of our technical experience. It seems our duty to contribute from time to time to the instruction of the public when there is opportunity to do so through proper channels. Such considerations impelled two of the staff to accept an invitation from the American Medical Association to contrib-

ute articles to a series on sex education. Dr. Corner's article, written in collaboration with Dr. C. E. Landis, of New York (bibliographic reference in Year Book No. 40), dealt with sex education of adolescent

boys and girls. Dr. Hartman dealt with information for the woman at menopause. Both articles were widely circulated in *Hygeia*, the Association's magazine for popular medical instruction.

THE MAMMARY GLAND

ACTION OF ESTROGENIC HORMONES

While a student and intern at the Johns Hopkins Hospital, Dr. Harold Speert made an extensive study of mammary-gland problems. Many of the animals and notes of Dr. Hartman's monkey colony were put at his disposal for this purpose. Some of the results were mentioned in Year Book No. 40.

One of Dr. Speert's experiments deals with the question as to how the estrogenic hormones act upon the mammary gland to make it grow. Certain experimental work in recent years has suggested the possibility that injected estrogens exert their effects through the pituitary gland. To test this question, Dr. Speert took advantage of the fact that estrogenic hormones are absorbed through the skin. Using immature male rhesus monkeys, he applied estrone in alcoholic solution to the left nipple, and alcohol alone to the right. In three such experiments the left mammary gland grew far more than the right. This result indicates that the action of the hormone was direct rather than through the pituitary gland, for otherwise a similar growth response of the two glands would be expected. It should be noted, however, that the experiment does not exclude the possibility of joint action of pituitary and estrogenic factors, as indicated by recent work of Turner and others.

CYCLIC CHANGES IN THE MAMMARY GLAND

In a preliminary report Dr. Speert discusses the cyclic changes in the mammary

gland. It has long been known that many women experience a sense of fullness and an increase in the size of the breast in the premenstrual phase of the cycle. Confirmation and analysis of these changes by histological methods have, however, been difficult to secure, because of technical difficulties in collecting and preparing the material. The mammary gland of the rhesus monkey is much easier to study, and the material can be collected under experimental conditions. Dr. Speert subjected 9 monkeys, having regular menstrual cycles, to periodic biopsy of the mammary glands. Whole mounts or spreads of the gland tissue were made as well as sections. He found a definite series of cyclic changes in relation to the cycle. Beginning 7 to 10 days before the onset of the cycle, the lobules begin to enlarge and in some instances the individual acini are dilated. The blood capillaries become engorged. The changes attain their height at about the time of menstruation and slowly regress thereafter. They occur only in ovulatory cycles.

HYSTERECTOMY AND THE MAMMARY GLAND

There are certain indications, not always clearly defined, and evidently varying from species to species, that the uterus has some sort of influence (presumably endocrine) upon the corpus luteum and the mammary glands. In the guinea pig, for example, it appears that removal of the uterus when there are corpora lutea in the ovary causes persistence of corpora lutea and concomitant growth of the mammary glands.

These effects have not been found in some other species. Dr. Speert observed a monkey from which Dr. Hartman removed the uterus on the 11th day of pregnancy. Biopsies of the mammary gland showed enlargement of the mammary lobules 5 days later, at the time of the expected maximal corpus luteum effect. Subsequent biopsies revealed retrogressive changes during the 6 weeks after operation. In this one case, hysterectomy apparently failed to delay involution of the corpus luteum and had no effect on the mammary glands.

SUPERNUMERARY MAMMARY GLANDS AND NIPPLES

In a careful review, Dr. Speert summarizes the literature on supernumerary mammary glands. These are relatively common in the human race, occurring in about 1 per cent of all individuals. Most of these accessory glands or nipples occur somewhere along the milk line, from axilla to groin. Their structure varies from an extremely rudimentary state to that of the typical breast. There is very little information about the condition in lower mammals, and Speert was able to find only eight reports of supernumerary nipples in apes and monkeys. To these he now adds 13 cases observed in approximately 1000 rhesus monkeys which have been studied in the Carnegie colony. Including one case previously reported by Hartman, the frequency of occurrence is about 1.4 per cent, which is within the order of frequency in the human species. In only 5 of these cases was glandular tissue associated with the accessory nipple. Supernumerary nipples were found susceptible to stimulation by local application of estrogenic hormone.

A guinea pig observed by Dr. Speert had an extra pair of accessory nipples. In this species such nipples are exceedingly rare. Single ones have been reported only twice, and an accessory pair only in one previous case.

"PALE EPITHELIUM" IN THE MAMMARY GLAND

Pathologists have been interested for many years in certain cells of the mammary gland, usually found lining mammary cysts. Because of their tendency to stain lightly as compared with the usual gland cells, these special cells are called "pale epithelium." They are generally found in the 4th and 5th decades of life. Their origin and their possible relation to cancer of the breast have been much discussed. It is possible that more than one type of cell has been placed in this category. Recently experimenters have noticed the appearance of cells resembling the "pale epithelium" in rabbits and rats which had received long-continued treatment with estrogenic hormones. Speert has now had an opportunity to study in this regard the mammary glands of Hartman and Geschickter's monkeys mentioned above, which received very intensive and long-continued treatment with estrone. In 4 of 8 castrated animals and 1 of 7 intact monkeys thus treated, pale cells developed. They appeared at various times after the 10th week of treatment. They most commonly occurred in solid islets, rather than in cysts as in the human cases. Speert concludes that these cells arise from the mammary epithelium and represent a metaplastic alteration of normal mammary-gland cells. Since none of these animals developed carcinoma, there is no support for any possible relation of the pale cells to the origin of malignant tumors.

CYTOLOGY

MYELOMATOUS TUMORS

Dr. Margaret Reed Lewis, of the Department's staff, is at present carrying on her work in the laboratories of the Wistar Institute of Anatomy and Biology in Philadelphia. Working with Dr. G. B. Mider, of the National Cancer Institute, Dr. Lewis has recently been studying certain transmissible tumors of mice. These tumors are produced, as described by Morton and Mider, by first treating mice of a dilute-brown strain by painting them with methylcholanthrene and afterward transplanting bits of the spleen, lymph node, or buffy coat of the blood of these mice into normal mice of the same strain. Myeloid tumors are thus induced. Lewis and Mider now find that such tumors may be transplanted serially into Bagg albino mice, in which they will grow, metastasize, and produce a general disturbance of the host animal just as in mice of the strain of origin (dilute brown). Up to 8 days after implantation the effects are indistinguishable. In the dilute-brown mice, however, the tumors progress until death of the animal, which occurs about the 12th day. In the majority of the Bagg albino mice, the tumors begin to regress after the 8th day, and within a few days the animals regain their normal health and appearance. Such mice are then immune against the growth of another implant of the same kind of tumor, but not to that of a sarcoma from the same or another strain. Here, then, is a very sharply defined, rapidly detectable difference between two strains of animals with respect to susceptibility to tumor growth, which should furnish opportunity for investigation of the biological and chemical factors influencing the growth of tumor grafts.

In another article Drs. Lewis and Mider

discuss the identification of the cells of these tumors. In Year Book No. 39 mention was made of a new way of identifying the cells of the blood-forming organs, introduced by Dr. Lewis, by studying their mode of locomotion and their characteristics of form while moving, in motion pictures of living cells in tissue cultures. When this method was applied to the tumors induced by methylcholanthrene, it was found that their cells resembled those of myeloblasts and differed from lymphoblasts and mononuclear phagocytes. The tumors are therefore properly classified as myelomas. The authors had an opportunity also to study the cells of two cases of spontaneous leukocytosis arising in dilute-brown mice. These cells resembled leukocytes in characteristic form and motion.

STUDIES ON LIVING SPINAL-GANGLION CELLS

About forty years ago the Strasbourg anatomist Bethe and the great Spanish histologist Ramón y Cajal brought the neurofibrils to the general attention of those interested in the nervous system. These are delicate threadlike strands, which in suitably stained preparations can be seen coursing in every direction through the cytoplasm of the nerve cells and passing from the cell into the axone fiber and the dendrites. Their complexity and sharp definition, as seen in preparations by Cajal's method, have led many neurologists to think of them as the fundamental channels of communication within the nervous system, like the individual wires in a telephone cable. On the other hand, the very existence of the neurofibrils has been denied, on the ground that they can be seen only after elaborate and somewhat drastic chemical treatment of nerve tissue. With the advent of the tissue-culture

method, efforts have been made to see the neurofibrils in living, growing nerve fibers and nerve cells. Some observers have reported seeing them, others have announced their absence.

Dr. Donal P. Murnaghan, who spent the year 1939-1940 in our laboratory as a traveling student of the National University of Ireland, again took up this question. He was able to cultivate cells of the spinal ganglia of chick embryos and newborn mice and to study them while living, under high powers of the microscope. He was able also to visualize by vital staining the mitochondrial granules and "neutral red bodies" of the living cells.

Murnaghan finds that neurofibrils are not visible in normal living cells in such cultures. Only when cells are suffering damage do fibrillar appearances become visible in the cytoplasm. He suggests that possibly there is something existent but invisible which becomes apparent in the moribund or nonliving cell under suitable conditions. He thinks that observers who have seen appearances resembling neurofibrils in living cells have been deceived by seeing the alignment of the mitochondria. The article is illustrated with very fine photographs of the living ganglion cells, made by Mr. Reather from Dr. Murnaghan's preparations.

THYROID AND ADRENAL GLANDS

ENZYME ACTIVITY OF THE COLLOID OF THE THYROID GLAND

One of the oldest enigmas of histology has to do with the thyroid gland. This organ is composed of rounded chambers or follicles. Behind the cellular walls of each of the follicles lies a network of blood vessels. From these vessels the cells of the follicles receive the ingredients from which they elaborate a secretion in the form of a thick fluid (colloid), which is then stored in the cavity of the follicle. When needed by the body the colloidal material or its active ingredients must obviously be reabsorbed, back through the follicle lining into the blood stream. A major ingredient of the colloid is a protein of large molecular size, thyroglobulin; just how such material can pass through living tissue with apparent readiness becomes a question. It has been suggested, and indeed actually demonstrated, that extracts of the thyroid gland contain a proteolytic enzyme which might catalyze the formation and the hydrolysis of thyroglobulin, so that the passage both ways through the follicular wall would be effected by

smaller molecular masses, which would afterward go in to be built up into thyroglobulin or come out from its hydrolytic breakdown.

Dr. Eduardo de Robertis, of Buenos Aires, while working with Dr. Gersh in the Anatomical Laboratory of the Johns Hopkins Medical School on a Rockefeller fellowship, obtained further evidence concerning this question. He was able, by using microdissection pipettes, to withdraw droplets of colloid from individual follicles of anesthetized rats. Such droplets, placed on gelatine plates under proper conditions, were able to digest the gelatine. This demonstrates the existence of proteolytic ferment actually in the colloid. The colloid is an optically homogeneous viscous fluid, of slightly acid reaction (pH 6.6). After the administration of pituitary thyreotropic hormone or of potassium iodide it becomes less viscous; but after a longer period of iodine administration the viscosity increases. The proteolytic enzyme gains activity in the acid range and loses it in the alkaline. Within the physiological pH range the activity increases after ad-

ministration of thyreotropic hormone and also temporarily after potassium iodide. The observations strongly support the hypothesis that an enzymatic mechanism is involved in the hydrolysis of the colloid protein and subsequent reabsorption of the products of hydrolysis.

BLOOD VESSELS OF THE ADRENAL GLAND

The isolation of hormones from the cortex of the adrenal gland has caused renewed interest in the anatomical structure of this gland and particularly in its blood vessels. The classic description of the vessels of the dog's adrenal, published 42 years ago by the late J. M. Flint, is limited to one species, and of course does not take into account modifications due to physiological states. Dr. I. Gersh, of the Department of Anatomy of the Johns Hopkins Medical School, and Dr. Arthur Grollman, formerly of the Department of Pharmacology, have studied the mouse and rat, using not only normal infant and adult animals, but also mice stimulated by low temperature and by thyroid extract to produce hypertrophy. They give a thorough and detailed account of the blood

circulation in the adrenal glands of these animals as it varies with age and condition. The most important point in their work is the demonstration that capillaries exist in the adrenal medulla (a fact which has been controverted so far as the mouse is concerned). The circulation through the cortex and that through the medulla seem to be distinct except that the blood from both drains into the medullary veins. This is an important matter because some have thought that the blood from the cortex passes through the capillaries of the medulla and can influence its function.

The vessels of the X zone, which is peculiar to the mouse, are found to be loose-meshed, with few anastomoses. As would be expected, the capillary network becomes much richer when the X zone is made hypertrophic by experimental stimulation. Attention is called to the alteration of the capillaries of the fascicular zone from the irregular capillary bed seen in the embryo and in small accessory glands to the elaborately parallel pattern of the mature gland, and an explanation of the final arrangement on the basis of physiological need is offered.

GROSS AND COMPARATIVE ANATOMY

The group of comparative anatomists in the Department of Anatomy of the Johns Hopkins Medical School, closely associated with the Carnegie Department of Embryology, has contributed this year a number of important articles on the anatomy of man, the other primates, and the vertebrates in general.

THE FEMORAL TROCHANTERS

Mr. A. Brazier Howell has discussed the homologies of the large bony processes or trochanters which characterize the head of the thighbone. There has been great difficulty in correlating the trochanters of

the various tetrapod vertebrates. Howell considers them from the standpoint of myology; that is to say, he regards the trochanters as associated with the attachment of muscle groups. The problem of correlating them thus becomes largely one of correlating homologous muscles. Howell concludes that, in summary, the mammalian lesser trochanter is a femoral group or iliopsoas process. The greater trochanter is a deep gluteal or partly peroneal group process with associated short flexor, chiefly tibial, elements around its margin and a superficial gluteal element either included or separate, in the latter case

sometimes causing a third trochanter. The adductor tubercle is the fourth trochanter of mammals. An adductor process also occurs in some marsupials.

The internal trochanter of *Iguana* is essentially a short flexor, largely tibial, and a deep gluteal or peroneal process. The faint process situated more laterally (dorsally), or external trochanter, is a femoral or probably iliacus process. The fourth trochanter of some fossil reptiles is probably a caudofemoral process.

In modern birds, the large lateral trochanter represents a fusion of the elements of the mammalian greater and lesser trochanters, but without the element (superficial gluteal) of the mammalian third trochanter and with, in the fowl, the element of the fourth trochanter. When the last is well defined it is a caudofemoral process.

THE SHOULDER OF THE ARMADILLO

Dr. Samuel S. Miles,¹ working at the suggestion of Mr. Howell, has described very fully the shoulder musculature of the nine-banded armadillo of Texas, *Dasypus novemcinctus texanus*. The matter is of interest because the skeleton and muscles of the shoulder in this animal are highly adapted to the act of digging. The shoulder joint permits movement in the front-and-back direction much more amply than rotation or abduction. The scapula and humerus are formed in such a way as to allow strong attachments of the muscles giving leverage in the antero-posterior plane, and bringing about retraction of the manus. For details of the musculature Dr. Miles' paper must be consulted.

¹The author of this competent study was killed in action in the South Pacific area, August 1942, while serving as medical officer of the U. S. Navy, attached to the Marine Corps.

A NEW FASCIA OF THE HUMAN BODY

The adult human body has been so thoroughly studied for hundreds of years, by anatomists prepared to detect the least novelty, that it is rare nowadays to have a new structure described. Dr. Ferdinand C. Lee, however, has called attention to a hitherto undescribed fascia situated between the serratus anterior muscle and the chest wall.

It was present to a greater or less degree in every one of the thirty bodies that were examined, being more evident in thin individuals, and being thickest near the inferior angle of the scapula. Microscopically, it is composed of connective-tissue fibers with a substantial interlacing of elastic tissue. The fascia, although present in a young chimpanzee, was absent in the ordinary laboratory animals. The function of the fascia is probably to provide a protective surface for the motion of the scapula.

THE HOMOLOGIES OF THE FOREARM FLEXORS

Probably no part of the body has been adapted, during the course of animal evolution, to as many different functional uses as the fore limb. For this reason its comparative anatomy, and especially the anatomy of its muscles, has been the object of much study and discussion. Dr. William L. Straus, Jr., who recently published an elaborate analysis of the extensor muscles of the forearm, now presents a study of the forearm flexors in urodele amphibians, reptiles, and mammals. The results, which trace in detail the development of the individual muscles from their original matrices or common muscle masses, cannot be summarized instructively here for the nonspecialist reader. The most interesting general point is that very few distinctively new muscles have been differentiated in the evolution of

reptiles and mammals; those present in these higher tetrapods can usually be recognized, partially or fully differentiated, amid the muscle groups of the amphibians.

THE LOCOMOTION OF GIBBONS

The question of the way in which the apes use their hands in walking was discussed in last year's report (Year Book No. 40) in connection with the studies of Dr. William L. Straus, Jr. It was pointed out that the gibbons, unlike the great apes, are able to extend their fingers when the palm of the hand is on the ground, so that they can assume the palmigrade position when walking. The great apes, on the other hand, must walk on their knuckles, because they cannot extend their fingers when in walking position. To what extent the gibbons actually utilize their adaptability to the palmigrade position has been questioned by Dr. Alěš Hrdlička, who reports gibbons that walked on their knuckles. Dr. Straus, in an interesting note, cites new evidence collected in the field by Dr. C. R. Carpenter. This shows that the mode of walking varies a good deal. The palmigrade pattern is among those actually used. An infant gibbon observed by Dr. S. L. Washburn also frequently placed its hands flat when walking. The present conclusion is that although adult gibbons seldom actually use the forearms for support when walking, when they do, they sometimes walk on their palms, thus retaining a capacity that has been lost by the great anthropoid apes.

RELATIVE CRANIAL CAPACITY IN PRIMATES

The cranial capacity, i.e. the volume of the cranial cavity, furnishes a close indication of the size of the brain, and is therefore from the anatomist's standpoint one of the outstanding characteristics of a race

of mankind or an animal species. In general, the larger the animal species, the smaller the relative size of the brain in proportion to the rest of the body. In any individual, moreover, the brain is relatively larger at birth than afterward.

There has been a dearth of reliable information about the relation between body weight and cranial capacity in the primates. In the case of many species, the number of specimens known to be normal and fully grown is small. Dr. Adolf H. Schultz, as part of his program of study of the physical characteristics and growth of the primates, has compiled the data on relative cranial capacity for 385 specimens of various species from marmoset to man. The marmosets rank lowest with respect to relative cranial capacity, followed in ascending order by the night monkeys (*Aotus*) and the howler monkeys (*Alouatta*) and then by capuchin monkeys, macaques, guenons, langurs, and proboscis monkeys. The spider monkeys and gibbons come next. All three great apes (chimpanzee, gorilla, orang) fit one curve which lies still higher on the scale, and the relative cranial capacity of man is at all ages far greater than that of any other primate. Dr. Schultz has been able to calculate the probable relative cranial capacity of the fossil man *Sinanthropus* (Peking man) and finds that it must have been nearer to that of recent man than to that of any great ape of similar body weight.

OBSERVATIONS ON A GORILLA AND AN ORANG

Through the cooperation of Dr. J. F. Fulton, of Yale University, Dr. Schultz has had an opportunity to make morphological observations on two adult female great apes of closely known age, the gorilla "Janet," formerly of the Bronx Zoo and more lately in the Yale colony, about 13

years and 3 months old at the time of death, and the orang "Lulu," which was in the Yale colony from 1932 until her death in 1941 at about 11 years and 4 months. Such dated specimens of the great apes are rare indeed. The description deals with many details, and a summary is difficult. Taking what he has learned from these two animals into consideration along with other evidence, Dr. Schultz concludes that (1) the three great apes reach adulthood at practically identical ages; (2) the permanent dentition is normally completed in the eleventh year; (3) growth in general ceases, as a rule, between the ages of 10 and 12 years; (4) the last happenings in skeletal development are the obliteration of most of the cranial sutures, the complete union of the clavicular epiphysis, and the final fusion of the bony rims at the iliac crest and at the lower angle of the shoulderblade. All this occurs generally between the ages of 12 and 14 years. In all probability rules 2, 3, and 4 apply equally to chimpanzee, gorilla, and orang. In man, as is well known, these phases of maturation take place at very much more advanced ages. This fact must be regarded as a profound, though perhaps comparatively recent, evolutionary specialization of man, which is unique among primates.

The paper is illustrated with two skillful portraits of "Janet" from the pen of the author.

GROWTH AND DEVELOPMENT OF THE PROBOSCIS MONKEY

As a participant in the Asiatic Primate Expedition of 1937, organized by Mr. H. J. Coolidge, Jr., Dr. Schultz was able to collect 51 specimens of the proboscis monkey, *Nasalis larvatus*. A few other specimens have also been available to him. His meas-

urements are recorded in a comprehensive paper which is an archive of data to be used later when the time comes for a general comparison of bodily proportions and growth in the primates.

Included among the illustrations are three handsome plates by the late celebrated medical illustrator Max Broedel, illustrating the facial appearance of this strange creature.

GROWTH AND DEVELOPMENT OF THE ORANGUTAN

In volume XXIX of the Carnegie "Contributions to Embryology" appears an extensive monograph by Dr. Schultz on growth and development of the orangutan. This article sums up the work of many years. It has been compiled from a large number of specimens from various sources, including the Asiatic Primate Expedition of 1937, several museums, and other collections. Dr. Schultz has made a very large series of measurements and other morphological observations, from mid-fetal life to old age. The results provide a mine of information which will be of great use in formulating the laws of growth and bodily proportions in primates. The summary alone comprises 3½ pages of facts, and we can do no more here than cite a few items.

Prenatal growth lasts 39 weeks. Post-natal growth appears to be completed sometime between the ages of 10 and 12 years. The males grow to be much larger than the females, which average only 49 per cent of the weight of the males (adult human females average about 81 per cent of the adult male weight). Female orangutans, like humans, can become pregnant long before their second dentition is complete. The order of eruption of the teeth resembles that in the chimpanzee, differ-

ing in many respects from that in man. Developmental anomalies of the permanent teeth and dental disease are very common. Disturbances of the growth of the skeleton are also very common in wild orangutans, and all sorts of disease conditions are evident in the skeleton, including healed fractures, sinus infections, and arthritic joints. About one-third of all adult wild orangutans have had broken bones.

It is as yet impossible to compare in detail the conditions of growth and development in orangutans with the corresponding conditions in many other primates. It can be concluded, however, that in general the ontogenetic processes of orangutan and chimpanzee are far more similar to each other than those of either of these species are to those of man.

The interesting and valuable collection of pen drawings of heads of primates which have accumulated in the course of Dr. Schultz' studies is augmented in this article by three notable portraits drawn by the author, illustrating respectively an infant orangutan, an adult female, and an adult male.

RELATIVE GROWTH OF LIMBS AND TAIL IN MACAQUE

From an investigation on the anthropoid apes, Dr. Hyman Lumer, of Fenn College, pointed out a few years ago that the relative growth of the limb bones conforms to the law $y = bx^a$, in which x and y represent two parts of the body and b and a are constants. Thus the plot of length of forearm, for example, against trunk length results in an exponential curve, and if these measurements are plotted logarithmically a straight line results.

From the data accumulated by Dr.

Schultz, Dr. Lumer and he now study in the same way the growth of the limb segments and tail in several species of macaque. A striking point which comes out at once is that in the rhesus monkey, for which the investigators had fetal as well as postnatal material, there is a break in each of the relative growth curves they plotted, at a value of x corresponding roughly to the time of birth.

Another point will be of great interest to those who are concerned with the difficult matter of the classification of monkeys. Bodily proportions are of course constantly used in distinguishing between closely related species. All the taxonomists have used the relative length of the tail, for example, as one of the means of distinguishing between the rhesus and the Java macaques. Relative growth curves like those of Lumer and Schultz not only are more precise than mere measurement of individuals, but also take growth into consideration and thus utilize relative proportions at various ages, not in adults only. Curves thus obtained for the relative growth of the tail are different for each of six species studied, except that the point for *Macaca irus*, of which adults only were available, falls practically on the curve for *M. sinicus*. The authors thus tentatively conclude that the genus *Macaca* does not constitute a single tribe, but is divisible into several groups. The five tribes which they are thus able to demarcate correspond for the most part to the subgenera of the macaques set up by Elliot in his *Review of the primates* on the basis of conventional taxonomic methods. The authors suggest that their method, if it could be applied to a large number of specimens, might well yield valid taxonomic categories and thus improve the groupings determined by naturalists on the basis of crude comparisons of bodily proportions.

THE NERVOUS SYSTEM

ISOLATION OF PART OF THE SPINAL CORD

Some years ago Dr. Sarah Tower found it possible to isolate a part of the spinal cord from incoming impulses, by transverse section at two levels and severance of the sensory roots between. These experiments, which were done on dogs, have now been confirmed in monkeys by Dr. Tower, with Drs. David Bodian and Howard Howe, all of the Department of Anatomy of the Johns Hopkins Medical School. In two out of three cases the isolated lumbosacral cord survived the experimental trauma. By suitable staining, the investigators obtained a picture of the intrinsic and motor mechanism of the cord, cleared of posterior root fibers and descending fibers. The reactions of the animals have confirmed the conclusion reached after similar study of isolated segments in dogs, that the mammalian cord mechanism operates only under the stimulus of arriving nerve impulses. Deprived of such excitation, the cord produces no activity which reaches effectiveness in the skeletal musculature.

FIBRILLATION IN INACTIVATED MUSCLE

When a muscle is deprived of its nerve supply by cutting of the nerve, it atrophies. To this well known fact Dr. Tower added three years ago the new observation that such a muscle undergoes ceaseless minute contractions of its fibers or parts of the fibers, a process called technically fibrillation, and continues in this peculiar state of activity for months, until atrophy sets in. The question now arises whether muscles made inactive by isolation of that part of the spinal cord by which they are supplied with motor fibers also undergo fibrillation. In a monkey with isolated surviving lumbosacral cord, the right sciatic nerve was cut. Muscles of the right thigh were therefore denervated, while those of the left thigh were inactivated without denervation. The former were found to fibrillate, the latter not. Atrophy developing under conditions of inaction without denervation may therefore be considered inactivation atrophy, or atrophy of disuse.

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DEPARTMENT OF GENETICS

Cold Spring Harbor, Long Island, New York

M. DEMEREC, *Acting Director*

The first annual report of the present Acting Director may be an appropriate place for a short survey of the problems covered by the work of the Department of Genetics. The Department was organized almost forty years ago (1904), when the science of genetics was in its early infancy—was, in fact, still an unnamed child, with another two years to wait before acquiring its present name. In 1902, when the Carnegie Institution was incorporated, interest in the new science of heredity was running high; therefore, it is not at all surprising that the Trustees took under consideration the establishment of a laboratory where work in the new field could be carried on. The first report of the Advisory Committee on Zoölogy includes the following statement: "As regards an experimental station, among the most important desiderata at present are experiments in heredity, in variation, in instincts, in modification, all of which should extend over a series of years and be planned systematically" (Year Book No. 1 [1902], p. 167). In addition, this first issue of the Year Book contains two memoranda written by prominent young biologists regarding plans for an experimental station for the study of heredity. One of these plans was accepted, and its author, Dr. C. B. Davenport, was appointed to take charge of the new laboratory.

It was realized at the time the laboratory was founded that heredity furnishes a valuable clue to an understanding of the mechanisms of organic evolution. Accordingly, the name "Station for Experimental Evolution" was given to the new division of the Institution. The young sci-

ence of genetics was not ready, however, for an immediate attack on the problem of evolution. The phenomena of heredity constitute one of the most important attributes of living matter; and heredity may and should be investigated as a fundamental physiological function, regardless of its bearing on organic evolution. Moreover, so far as the evolutionary implications of genetics are concerned, it took almost forty years to forge the concepts, experimental techniques, and quantitative methods with the aid of which a scientifically rigorous study of evolutionary changes could be undertaken. Finally, the heredity of man presents problems that require still different methods for their solution, although it is becoming more and more evident that this study is a part of the larger field of evolutionary genetics. Shortly after the Eugenics Record Office was taken over by the Institution, the two laboratories were combined (1921) under the title Department of Genetics.

Although the Station was organized by a zoologist, one of its first three staff members was a botanist. Thus, from the very beginning the work of the laboratory was arranged so as to break down the conventional dividing lines between sciences, and the new problems were attacked by the concentrated effort of representatives of several branches of science. This approach was, in a way, prophetic, for the present stage in the development of biology is characterized by a trend away from specialization and toward a closer integration of biological disciplines. Such an attitude toward research is still one of the outstanding characteristics of this Department.

From the time the laboratory was organized, the work with plants and that with animals have been carried on concurrently. When it soon became evident that for the solution of certain fundamental problems the help of a chemist was essential, a chemist was added to the staff (1909); and when, later on, the problems under consideration branched out into the related field of physics, physical equipment was procured and the cooperation of physicists was enlisted. From its early days, problems of human heredity were included in the research program of this Department, and some of the most important pioneering studies in that field were carried on here. The interests of the laboratory soon expanded far beyond its facilities, and as a consequence it has always cooperated with other institutions in research on problems where such cooperation was advantageous. Cooperative work has increased with the growth of the Department, and today constitutes an important part of its activity.

The Carnegie Institution's interest in research on problems related to genetics did not stop with the establishment of this Department. A glance through the reports published in the Year Books will show that the research of many scientists working in this field has been furthered by the Institution's support. The list of Research Associates contains the names of W. E. Castle, E. B. Wilson, T. H. Morgan, C. B. Bridges, A. H. Sturtevant, C. E. McClung, R. Pearl, H. E. Crampton, E. B. Babcock, H. D. Goodale, L. R. Dice, F. B. Sumner, Th. Dobzhansky, and J. Schultz. A particularly strong measure of support was provided during those early days when genetics was in special need of recognition and assistance. This backing given to genetical research by the Institution undoubtedly accounts to a large degree for the fact

that the United States now occupies a leading position in this branch of science.

All along the line, this Department has made significant contributions toward the solution of current problems in genetics. Davenport's early work with poultry, canaries, and sheep, as well as on the inheritance of eye color and other characters in man, furnished classic examples of Mendelian inheritance; the work of G. H. Shull with *Oenothera*, *Capsella*, and *Me-landrium*, and particularly with maize, contributed fundamental knowledge which has greatly improved the methods of plant breeding; the pioneering research of C. C. Little opened up a road for experimental studies of the inheritance of cancer; and the brilliant work of the late John Belling laid the foundation for cytogenetics, and made possible the unique cytogenetic research carried on with *Datura* by Blakeslee and his group. MacDowell's studies of embryonic growth in mice, and MacDowell and Potter's studies of leukemia in mice, are but two examples of painstakingly thorough research which has contributed much toward an understanding of these problems. New vistas in the endocrine field have been opened up, and better understanding of the relation between endocrines and heredity has been achieved, through the work of Riddle and his associates. C. W. Metz' studies with *Sciara* focused attention on a hereditary mechanism strikingly different from those usually found in other organisms; and the cytological research of Kaufmann, as well as the genetical and cytological work carried on by the gene group, has extended the sum of knowledge concerning the nature and action of genes. The statistical studies of the late Arthur J. Harris made a significant contribution to biometry; the work of A. M. Banta with *Cladocera* clarified the question of germinal and somatic variations in parthenogenetic animals; and

the studies of Davenport and Steggerda have made an important contribution to our knowledge of growth in man.

The development of genetics has been exceptionally rapid. At present, genetics is only a little more than forty years old—very young for a scientific discipline. But discoveries and spectacular events in this field follow each other in such rapid succession that textbooks and reviews published only a few years ago are now hopelessly outdated. New problems and new lines of approach are being discovered at a rate higher than that of the solution of the classic problems. With the passing of infancy and the onset of maturity of the science, the research methods used by geneticists are undergoing a rapid change. From the simple biological methods employed at first, the experimental technique has evolved into a complex structure requiring the use of optical, physical, and chemical instruments. From the purely biological science of early days, genetics has developed into a science where cooperation with physics, chemistry, and mathematics is essential.

One of the three fundamental groups of problems facing modern genetics today relates to the mechanism whereby hereditary characteristics are transmitted from parents to offspring. What is the chemical and physical structure of genes? how do they reproduce? how do changes in genes occur? what is the relation between genes and chromosomes?—these are but a few of the questions still waiting to be answered. These problems are being intensively studied at the Department, in cooperation with workers in a number of other institutions—particularly with Dr. A. Hollaender, biophysicist at the National Institute of Health, Bethesda, Maryland, and with a number of physics laboratories in New York City.

The second cycle of problems concerns

the action of genes in development. Why does a single cell, a fertilized ovum, develop into a complex organism, and how do the genes and chromosomes exert their determining influence on this process? Numerous attempts have been made to solve these problems, but so far all have failed for lack of fundamental information and reliable methods of approach. The work of MacDowell and Potter and of Riddle and his group is contributing this essential information.

The third cycle of problems involves the processes of change within groups of organisms (populations), which in a broad sense might be called organic evolution. It required almost forty years for genetics to accumulate information needed for work on this problem, and today the basic methods for the work are available. The Department, as now organized, is participating in research on this problem, in close collaboration with Professor Th. Dobzhansky, of Columbia University, who is a Research Associate of the Institution.

The field covered by genetics is so wide that research can most effectively be carried out through cooperation and close contact between various research groups. The location of this Department is admirably suited to such cooperative arrangements. It is situated almost in the suburbs of New York, where there are numerous research establishments, and this enables the staff of the Department to participate in the scientific life of that city. At the same time it is sufficiently secluded to be attractive to scientists connected with universities and colleges as a place to spend their vacations in congenial work. The Department has regularly a number of such summer guests, who furnish a stimulus to our research program. Two years ago, a closer collaboration was established with the neighboring Biological Laboratory of the Long Island Biological Asso-

ciation, and thus the opportunities for summer research have been greatly enlarged. Through the Symposia on Quantitative Biology, held yearly at the Biological Laboratory, we are now able to utilize a well established international conference for the discussion of problems in which our Department is interested.

The past year has brought about significant changes in the Department. At the end of November 1941, its second director, Dr. A. F. Blakeslee, reached the retirement age and relinquished his post after twenty-six years of distinguished service as staff member, assistant director, and director. During this time Blakeslee enjoyed unequaled opportunities for research, which he utilized to the fullest extent. Under his leadership, genetical work with *Datura* has been developed, and outstanding discoveries have been made in many fields of genetics and cytogenetics. Blakeslee and his co-workers remained with us until September 1942; he then transferred to Smith College, where he will be William Allan Neilson Research Professor of Botany and continue with his investigations as a Research Associate of the Carnegie Institution.

During the past year the Department has been fortunate in having as a guest investigator Dr. Barbara McClintock, a well known research worker on the cytogenetics of maize. Her stay here has invigorated our research program.

As a result of close collaboration with the Biological Laboratory, a number of geneticists worked here during the summer of 1942, making use of the facilities of the Laboratory and the advantages that our Department has to offer. In June a ten-day symposium on "The Relation of Hormones to Development" was held at the Biological Laboratory and was attended by over a hundred scientists. The program of this international conference

was closely related to the work of the Department, and our members derived profit and stimulus from these meetings.

A brief summary will be given here of the individual reports of the various research groups for the year ending September 1, 1942; the reports in full are printed on the succeeding pages.

Nearly six years of study of the role of hormones in the regulation of the maternal instinct in rats has been concluded and the results have been analyzed and published by Riddle, Lahr, and Bates. During embryonic life the hormones of the anterior pituitary gland influence the growth and development of the sensorimotor mechanisms which are later capable of stimulation to sex drive or to maternal drive. In later stages of life the pituitary hormones have been found to provide the sequence of stimuli that results in unlearned maternal behavior. The sex drive, or its unexpressed foundations, is apparently a necessary precursor of the maternal instinct; and thus pituitary gonadotrophins play a part in the origin of the latter instinct, although their output is inhibited temporarily by the agencies that induce maternal behavior. Interrelations among hormones are such that, directly or indirectly and under suitable conditions, several of them promote the exhibition of the maternal drive; but the study produced much evidence that this instinct, which is the last to arise in the life cycle, is provoked primarily by prolactin.

A type of prenatal loss that becomes selective for a given mutation only under certain conditions has been found by the group studying mouse genetics. Mice carrying the screw-tail mutation reach birth as successfully as normals when the prenatal loss of normals is low, but as this increases the proportional loss of screw-tails is progressively greater. This may provide an

explanation of other defective ratios or irregular results.

An excellent illustration of the manner in which a mutation can provide an interpretation of normal developmental processes has been found in the case of the sternum of the screw-tail mouse, which is unique in lacking all signs of division into sternebrae. The conditions associated with the absence of segmentation of the sternum have provided a clue to the conditions responsible for its presence. At the end of each rib a center of new growth is established in the early sternal material. In screw-tails the right and left members of a pair of these growth centers are so far apart that a continuous longitudinal band of fully matured cartilage runs the length of the sternum, before the first deposition of bone. In normals the right and left pairs of these growth centers are so close together that they join, so that immature cells from one side meet immature cells from the other side, and divide the fully mature cartilage into a series of separate masses. This difference determines the presence or absence of segmentation, for bone can be deposited only in fully matured cartilage.

During the past year the gene group worked on a number of problems in which X rays, neutrons, ultraviolet and near infrared rays, and chemicals were used to induce changes in genes and chromosomes and these changes were studied by genetical and cytological methods. The members of the group collaborated with Drs. A. Hollaender and P. A. Cole, of the National Institute of Health, Bethesda, Maryland, and with Dr. I. Gersh, of Johns Hopkins University, in experiments with ultraviolet and infrared radiation; with Dr. S. Zamenhof, New York, in experiments with deuterium; and with the Columbia University cyclotron group, under the di-

rection of Dr. J. R. Dunning, in experiments with neutrons.

Over a period of eight years, data have been accumulating on the correlation between genetic loci and the bands visible on salivary-gland chromosomes of *Drosophila*. This material has been summarized by Demerec and Sutton, and the positions of 44 loci determined. In several instances, the position has been localized to a region covering only one band. Demerec has found a gene in the wild-type Swedish-b stock which increases the mutability of other genes. In collaboration with Zamenhof, he has made an unsuccessful attempt to induce mutations with deuterium. Fano has completed the analysis of an interesting gene which when present in a female prevents hatching of about 80 per cent of the eggs laid by that female.

The preliminary studies of Kaufmann, in collaboration with Hollaender, on the combined effects of X rays with the near infrared or ultraviolet radiation promise to furnish valuable data concerning the factors involved in chromosome breakage and recombination. The high degree of breakage and the great complexity of recombination that may follow such treatment of *Drosophila* sperm is revealed in a rearrangement involving at least 32 points of breakage.

The production by neutrons of dominant and recessive lethals is the object of an extensive new experiment being carried on by Fano. Previous reports, indicating that recoil protons have a good chance of producing more than one recessive lethal at a point where they hit, have not been confirmed. Neutrons seem to be more efficient than X rays in producing lethals connected with chromosomal breaks; but they are less efficient in producing isolated recessive lethals appearing as gene mutations. This situation is contrary to the one

observed in ultraviolet experiments with both *Drosophila* and *Neurospora*, which show a lowered rate of chromosomal breaks as compared with gene mutations.

Demerec, Hollaender, Houlahan, and Sansome undertook a comparative study of genetic effects produced on the fungus *Neurospora* by ultraviolet and X rays. Of the six wave lengths between 2280 and 2967 Å that were used, 2650 Å was found to be most effective in producing mutations. It is of interest to note that nucleic acid has maximum absorption in this region of the spectrum. In the case of X rays, the frequency of mutations increased with the dosage applied; in the case of ultraviolet radiation, the mutation rate increased up to a certain point and then decreased. The "semilethal" type of mutant has been found very frequently among the changes produced by ultraviolet treatments, but has occurred rarely among the X-ray-induced mutants. The meaning of the observed differences between ultraviolet-treated and X-rayed material is being investigated.

Brehme has completed the revision of the manuscript of the late Calvin B. Bridges on "The mutants of *Drosophila melanogaster*," and has prepared it for publication.

It has been known for a number of years that chromosomes may be broken by X rays, by a mechanical pull, or by some undetermined force. It has been known also that broken ends may fuse, thus producing various chromosomal aberrations, such as translocations, inversions, and deficiencies. Notwithstanding many efforts to discover them, however, the basic processes responsible for the breakage-fusion event were not understood. Particularly puzzling was the question whether fusion occurs immediately after a chromosome is broken or whether a broken end may remain "unsaturated." A convincing answer to this question has been obtained

by McClintock. She verified the unsaturated state of a recently broken end of a chromosome, when two nuclei, each of which had a chromosome with a broken end, were allowed to merge, and it was found that the two broken ends, derived from separate nuclei, could fuse. Similarly, she observed that when two recently broken ends enter a dividing nucleus, fusion may occur between these broken ends. When three recently broken ends are present in a nucleus, fusion may occur between two of the three ends. The third end "heals"; it permanently loses its unsaturated state, that is, its ability to fuse with any unsaturated broken end. McClintock likewise determined that even when two unsaturated broken ends are present in a nucleus, healing may sometimes occur before union of the broken ends has taken place. Following this healing, no fusions occur.

Continued investigation by McClintock of the action of a progressive series of homozygous deficiencies of terminal segments of the short arm of chromosome 9 of maize have shown that deficiencies up to and including the terminal third of this arm have very little effect on pollen development. Pollen grains with terminal deficiencies of a chromomere or less are completely functional. Those with longer deficiencies do not function. All the deficiencies studied can give viable and functional embryo sacs and eggs. Endosperms that are homozygous for small terminal deficiencies are normal. The seedlings, however, are modified: pale-yellow seedlings occur when the homozygous deficiency is short, and white seedlings occur when it is slightly longer. The genetic behavior of these deficiency mutants is typically Mendelian. They are allelic, and dominance is an expression of the extent of the deficiency. A slightly longer homozygous deficiency causes early death of the

embryo. The effects on endosperms of deficiencies longer than a terminal chromomere were studied by means of the variegation method, utilizing the behavior of recently broken chromosomes. Endosperm development may be completely normal when a homozygous deficiency of two terminal chromomeres is present. Beyond this region, only patches of homozygous deficient cells, surrounded by normal cells, will develop. As the homozygous deficiency becomes progressively longer, the rate of development, the color of the aleurone, and the starch formation are progressively reduced except for the layer of cells immediately adjacent to normal cells. The cells in this layer appear to develop normally. This suggests that some diffusible substance or substances necessary for development are not produced by the homozygous deficient cells, but may be supplied by normally developing cells. The phenotypic effects of such large homozygous deficiencies are relatively mild. This could be understood if maize were a derived polyploid.

Certain fundamental principles established in genetics can be applied directly to a number of problems met in breeding work with plants and animals. As a consequence of the emergency created by the war, the Bureau of Plant Industry of the U. S. Department of Agriculture acquired a large number of new plant-breeding projects which require a quick solution. In order to facilitate the work, parts of this new load were assigned to various laboratories competent to handle them. Our Department was very glad to cooperate with the Bureau, and has taken up, through Warmke, several projects which it is well equipped to handle. These include an attempt to produce a strain of fiber hemp with greatly reduced marihuana content, and a cytogenetic analysis of the rubber-producing Russian dandelion.

Warmke finds a wide variation in the drug content of individual hemp plants. This is encouraging as a starting point for selection and breeding experiments. The Russian dandelion is shown to be self-sterile and a basic diploid with normal sexual reproduction.

Working with *Datura*, Bergner has continued her analysis of chromosomal changes that have occurred in the evolution of that species; and Satina has made progress in her analysis of the developmental history of the various organs and the contributions of the three germ layers by means of periclinal chimeras. Avery has completed the tests on mutation rate in 22- and 39-year-old seeds which had been stored under especially favorable conditions. He found that the rate is not so high in the old seed as in 10-year-old seed stored in the laboratory.

Steggerda has continued with research in anthropology and human genetics. By comparing the measurements made on Navajo and Dutch children last year with those made in 1931-1934, he found a significant trend toward increase in weight and height among the children of today as compared with children of the same age group seven to ten years ago. A similar trend has been observed by several scientists, but this is the first time that measurements have been made by the same person using a similar technique. Steggerda has completed the analysis of data involving measurements of 100 Negro men from Tuskegee Institute, and compared them with a similar set of data supplied by Professor H. H. Plough on white college students from Amherst. Although the weight for the two groups is approximately the same, the Negro students are about one inch shorter. This is entirely accounted for by the shorter trunk of the Negroes, who also have broader shoulders

and longer arms than the Amherst students.

In order to compare anthropometric technique as used by various scientists, Steggerda had twenty-one investigators measure the same subject. The results of these measurements show considerable variation. These data constitute a starting

point for the standardization of anthropometric technique. At the request of the Smithsonian Institution, Steggerda is making a survey of the known anthropometry of South American Indians. This study now includes data on more than 80 tribes, and covers the material contributed by 132 investigations.

DATURA STUDIES

A. F. BLAKESLEE, A. G. AVERY, A. D. BERGNER, AND S. SATINA

EVOLUTION OF CHROMOSOMES IN NATURE

Dr. Bergner has continued her analysis of the gross chromosomal changes that have occurred in the evolution of the herbaceous *Datura* species. In the past fourteen years it has been customary to study and to carry along concurrently many different cytological problems. This procedure has been necessitated by the fact that one obtains commonly only two generations per year. During the past year a few of those problems which were nearest completion were selected for completion if possible by the end of this year.

Whenever necessary, technical "speed-ups" have been used. For instance, in order to determine the modified chromosomes of prime type 96, tester races were crossed to heterozygous PT 96, since the latter has not yet been obtained in the homozygous condition. This necessitated looking at twice as many hybrids, since only a half of the gametes carried the modified PT 96 chromosomes, but a year of time was saved. Also, in the cross of a heterozygous interchange from *D. pruinosa* to *D. ferox* and to *D. discolor* and in *intra se* crosses of *D. metel*, the usual dormant period of seeds was eliminated by peeling off the outer seed coat of seeds as soon as they ripened, breaking the inner seed coat, and planting them immediately in soil. This process, although tedious and

time-consuming, shortened the generation by two months.

In the 1941 annual report, one of the natural prime types of *D. stramonium* (PT 96) could not be included in the table because the interchanged chromosomes had not been determined. They are 7·19 and 8·20 instead of 7·8 and 19·20 of PT 1. This PT was obtained from a single race in Ohio and hence is included among the sporadic PT's.

In the same table, three of the modified chromosomes of *D. pruinosa* and of type 2 of *D. leichhardtii* were left blank. They have since been determined to be 11·16, 12·22, and 15·21. This determination proved especially refractory because of the slight difference in size between the 15·21 and 12·22 chromosomes, and because terminalization is complete at the ·21 end. Inconclusive evidence was furnished by crosses of a PT 3 from *D. quercifolia* and of *D. stramonium* PT 91 with this interchange from *D. pruinosa*, which could be carried along only in the heterozygous condition. This necessitated crosses with *D. ferox* and *D. discolor*. It has not been possible to carry along this same interchange when extracted from type 2 of *leichhardtii*, but previous crosses between it and both *pruinosa* chromosomes and this particular interchange from *pruinosa* have shown that, so far as the chro-

mosome ends are concerned, the interchange is identical in the two species. This conclusion is especially interesting since *D. pruinosa* is endemic in Mexico and *D. leichhardtii* in Australia. Since these two species are rather closely related in morphological characteristics, the geographical location of their common ancestor would be a matter of interest.

As indicated in Year Book No. 40, *D. inoxia* will not cross directly with *D. stramonium* but will cross with *D. leichhardtii*; also it has been impossible to isolate the *stramonium* tester races in the homozygous condition, after repeated backcrosses onto *D. leichhardtii*, with the exception of PT 9. Therefore, in making crosses to *D. inoxia*, it was decided to use these tester races when they are heterozygous, since half the offspring should carry the tester chromosomes. During the past winter heterozygous PT's 2, 3, 7, 10, 17, 34, 40, 49, 61, 90, and 91 were obtained in plants which resemble *D. leichhardtii*. These plants were kept alive during the spring and summer by grafting. They have been used as the female parents in crosses with three tester races of *D. inoxia*, SI's 115, 352, and 1080, and also in crosses with two tester races of *D. meteloides*, SI's 121 and 948. It is hoped that at some time in the near future these seeds can be planted and the chromosomal configurations in the hybrids studied, so that the chromosomal end arrangements of the races of *D. inoxia* and *D. meteloides* can be determined.

The seeds of many of these species crosses rarely germinate, and further difficulty is encountered in the tendency toward asynapsis shown by *D. inoxia* (and to a lesser extent by *D. meteloides*). During the past year a few more hybrids were available for study, so that our knowledge is enlarged somewhat. In figure 1 of the last annual report (Year Book No. 40, p.

224), the chromosome arrangement in the cross between *inoxia* type 2 and homozygous PT 9 is incomplete. This has since been determined to be $\odot 8 + \text{ch} 8 + \text{ch} 4 + 2$ bivalents (\odot = circle; ch = chain). From the crosses of *inoxia* type 1 and type 2 to *stramonium* PT 9 ($20 \cdot 19 \cdot 23$ and 24 chromosomes), 2 of their 12 chromosomes are now known to be the $19 \cdot 20$ and $23 \cdot 24$ chromosomes. Therefore the end arrangements of these two are identical with two of *stramonium* PT 1.

Also, a plant was obtained from the cross of extracted *stramonium* PT 1 to *inoxia* type 3. It showed $\odot 10 + \odot 4 + 5$ bv. This $\odot 10$ indicated that the interchange between *inoxia* type 1 and type 3 involves 1 chromosome from those 4 which induce a $\odot 8$ and 1 from 2 which induce a $\odot 4$ with *stramonium* PT 1.

Two species crosses which involve *meteloides* type 1 were studied. The cross of *meteloides* type 1 to *stramonium* 11 · 16 + 12 · 15 gave a hybrid which showed $\odot 8 + \odot 4 + \odot 4 + \odot 4 + 2$ bv. A cross to *stramonium* PT 9 gave a hybrid which showed $\text{ch} 10 + \odot 4 + \odot 4 + \odot 4 + \text{bv}$. The latter cross shows that the $23 \cdot 24$ chromosome is involved in the $\odot 8$ interchange, but the $19 \cdot 20$ chromosome has ends identical with those of *stramonium* PT 1.

A cross of *meteloides* type 2 to *stramonium* PT 9 showed a $\text{ch} 14 + \odot 4 + \odot 4 + \text{bv}$. This type 2 also has a $19 \cdot 20$ chromosome, whereas the $23 \cdot 24$ chromosome is involved in the postulated interchange of 6 chromosomes (the cross of type 2 to other species has not yet been studied cytologically). The $\text{ch} 14$ further indicates that the interchange between *meteloides* type 1 and type 2 involves 1 chromosome from those 4 which induce a $\odot 8$ and 1 from 2 which induce a $\odot 4$ with *leichhardtii* type 1.

Although species crosses involving *D. metel* are limited to two rare crosses with

D. meteloides and one with *D. inoxia*, 61 races of *D. metel* have been used in *intra se* crosses. This species, which is widely distributed in tropical and semitropical regions, has horticultural value because of the greater variety of flower color and doubleness of corolla. There is only one widespread chromosomal type, but four others have been distinguished. Correlation of these chromosomal types with flower color has disclosed geographical localization of the sporadic types. Completion of this study has been delayed by the slow maturation of *D. metel* in this latitude, many races requiring more than a full year before flowering.

PERICLINAL CHIMERAS

Miss Satina has made progress in her analysis of the developmental history of the various organs of *Datura* and the contributions of the three germ layers by means of periclinal chimeras.

In 1941 detailed studies were begun in an attempt to analyze the structure of the carpel in *Datura stramonium* and to determine, by the use of periclinal chimeras, the contribution of each germ layer to the development of the carpel. During the past year this work has been continued and is still in progress. At present it can be stated that the initiation and development of the various parts of the carpel (carpel wall, septum, false septum, and placenta) differ from those of the leaf, sepal, and petal.

The initiation and development of the ovule during very early stages resemble those of the stamen and depend primarily on the activity of the innermost germ layer, L III. The cells of the middle germ layer, L II, form only the subepidermal layer. In later stages, the second layer becomes more active and contributes to the forma-

tion of the nucellus from which the megaspore mother cell differentiates. The integument of the ovule is formed by the cells derived from the outermost germ layer, L I. The megaspore, and later the embryo sac, is covered by the tissue of the integument of epidermal origin, except at the chalazal end, which is formed by cells of the nucellus.

Studies on incompatible $2n \times 4n$ and $4n \times 2n$ crosses in *Datura*, which were begun in 1941 with the cooperation of Mrs. E. Sansome, were extended this year. For a better understanding of the processes observed and of the results obtained in the previous year, the crosses were made using as males $4n$ or $2n$ plants with the dominant gene Bz. Tetraploid L1 and various types of periclinal chimeras with $2n$ egg cells ($4n\ 4n\ 2n$; $2n\ 4n\ 2n$; $2n\ 4n\ 4n$; $8n\ 4n\ 4n$) and with $1n$ egg cells ($4n\ 2n\ 2n$) were used as females. The $4n \times 2n$ crosses gave a larger number of seeds than the reciprocal crosses, but the germination of these seeds was poorer than in the $2n \times 4n$ crosses. Two hundred and twenty offspring from 123 pedigrees were brought to maturity; 91 plants were offspring from the $4n\ \text{♀} \times 2n\ \text{♂}$ crosses, 129 plants from the $2n\ \text{♀} \times 4n\ \text{♂}$. The offspring from the $4n \times 2n$ crosses were predominantly diploid (51 $2n$, 23 $3n$, 13 $4n$, and 4 ?). The offspring from the $2n \times 4n$ crosses were predominantly tetraploid (113 $4n$, 2 $3n$, 3 $2n$, and 11 ?). All but 4 of these offspring, whether $2n$, $3n$, or $4n$, carried the Bz gene, and thus they presumably developed from fertilized eggs. Further studies are being made, and seeds have been collected for a survey of the next generation to determine how much of the chromosomal constitution in each case was contributed by the male gamete which was tagged by a dominant gene.

MUTATIONS FROM BURIED SEEDS

Among the various gene studies under way, perhaps the most interesting is that on the mutation rate from old seed, carried on by Mr. Avery.

In 1933 it was shown by pollen-abortion records that the mutation rate in *Datura* was increased by the aging of seed stored under ordinary laboratory conditions. At that time it was shown that the percentage of mutations found was roughly proportional to the age of the seeds from which the plants came. Seeds less than 1 year old gave a mutation rate of less than 1 per cent. The highest rate, 8.7 per cent, was obtained from seed that was from 7 to 8 years old. Seeds stored under laboratory conditions have failed to germinate when more than 10 years old. There seemed to be an increase of about 1 per cent for each year that the seed had been aged; thus, the rate of mutation obtained from seed 6 years old was 6.1 per cent. In the F_2 generation from these plants a total of 11 new visible types due to mutation was obtained. Mutations of types that show as visible morphological effects were about one-third as frequent as those that caused pollen abortion. The seed used in these experiments was of our highly inbred Line 1. It has been repeatedly shown that the normal rate of mutation in this standard line of *Datura* is very low.

In the summer of 1933 it was possible to obtain samples of soil from the unexcavated parts of the cellar of a house built in Virginia 22 years previously. From these soil samples more than 500 *Datura* plants were obtained. Examinations of the pollen of these plants grown from seed that had apparently been buried for 22 years in the soil revealed that the rate of mutation (1.8 per cent) was scarcely higher than that of the controls, and very much lower than that obtained from seed stored

on the laboratory shelf for less than half as long.

During the past year it has been possible to make a further study of the mutation rate from old seed. Through the kindness of Dr. E. H. Toole, of the U. S. Department of Agriculture, a quantity of *Datura* seed was obtained that had been buried in the open ground for a known length of time. In 1902, samples of a large variety of crop, flower, and weed seeds were buried in the soil near Washington, D. C. The seeds of *Datura* that went into this experiment had been collected from wild plants growing near the Potomac River near Washington. Each sample of seed was placed with soil in a small earthen flower pot and buried directly in the soil. At intervals of 5 or 10 years a few of each lot of seed had been removed and tested for germination by the Department of Agriculture.

From Dr. Toole two lots of seed were obtained: one lot (A) of 188 seeds had been buried at a depth of 18 to 22 inches, the other (B) of 179 seeds had been buried from 36 to 42 inches below the surface. These seeds, with the surrounding soil, were sent to us in sealed metal containers. Upon arrival here the water content of A was found to be 7.15 per cent and that of B, 10.05. Although the seed was more than 39 years old, its germination was exceedingly good. Lot A gave 182 seedlings, or 96.8 per cent, and B gave 176 seedlings, or 98.3 per cent. These plants were grown in the greenhouse during the past winter. The only recordable abnormality among the 356 plants that grew beyond the seedling stage was the frequent occurrence of large or small spots or flecks on the surface of the leaves. These spots were very clearly defined and were usually paler than the surrounding areas. Their exact nature has not yet been determined.

The condition of the pollen of all of these plants was determined. Owing to the unreliability of pollen determinations made of plants grown in the greenhouse, it was impossible to establish a rate of mutation from the occurrence of plants showing high amounts of pollen abortion. Plants that genetically should have a low proportion of aborted pollen may show a high proportion of abortion when grown under greenhouse conditions, although plants with a genetically high proportion of abortion never have consistently normal pollen. As there were very few plants that showed any abnormal pollen abortion, it was evident that there had been very little mutation causing pollen-abortion types.

During the present summer F_2 progenies have been grown from 78 of these plants from 39-year-old seed. Two of these showed segregation for pale-leaved types, and one segregated for a recumbent type called "lazy." In addition to these three new types, which were presumably brought about by recessive mutations, there was one progeny that segregated for a type somewhat resembling the $2n + 15 \cdot 16$ primary. This also must be recorded as a gene type, since Dr. Bergner has determined it to have the $2n$ number of chromosomes.

The pollen of these F_2 plants was examined as a further check against the possibility that pollen-abortion types may have been overlooked when the pollen determinations of the parents were made. None of the 78 cultures was found to segregate for individuals with a high percentage of aborted pollen. In view of the fact that four new "visible" types were ob-

tained, it is surprising that no pollen-abortion types were found, as in all previous experiments the pollen-abortion types have been more frequent than the visible types.

From the 78 plants tested by F_2 progenies, there were recovered only these four mutations; this would be a rate of 5.1 per cent. This is considerably higher than that obtained from controls, but is much lower than that obtained from seed "aged" under laboratory conditions.

The low mutation rates obtained from the 39-year-old seed, as well as from those 22 years old, indicate that age alone has little if any part in causing an increase in the rate of mutation in *Datura*. The high mutation rate apparent in plants grown from seed stored on the laboratory shelves was therefore probably brought about by other factors than age alone, probably by the higher temperatures. Experiments conducted jointly with the Boyce Thompson Institute showed that *Datura* seeds held at various high temperatures (45° to 80° C.) for short periods (2 hours to 5 days) had a higher rate of mutation at the higher temperatures. Although no experimental data are available, it may be suggested that the probable reduction in the amount of oxygen surrounding the buried seed may also have played a part in keeping down the rate of mutation. Plants from either of the lots of buried seeds are not strictly comparable with those of our standard Line 1, which have been used as controls and which also came originally from Washington. There is no evidence, however, that either of the "buried seed" races would be expected to differ from Line 1 in mutability.

MAIZE GENETICS

BARBARA McCLINTOCK

THE BEHAVIOR OF "UNSATURATED" BROKEN
ENDS OF CHROMOSOMES

In all cases involving rearrangements of segments of chromosomes which give rise to translocations, inversions, deficiencies, etc., it has been necessary to postulate some force that breaks a chromosome and some force that results in the permanent 2-by-2 fusion of the broken ends. Previous investigations in maize on the mitotic behavior of ring-shaped chromosomes had suggested that fusions may occur between two recently broken ends of chromosomes which enter the same nucleus. Such broken ends may be considered "unsaturated," i.e., capable of fusion with similar "unsaturated" broken ends, until fusion with another broken end occurs or until the end loses its capacity for fusion. To determine whether such an "unsaturated" state exists, male gametes containing a chromosome 9 whose short arm had been broken by mechanical pull at the previous anaphase were united with female gametes containing a similar recently broken chromosome 9. The zygote formed received from each gamete nucleus a single chromosome with a single recently broken end. On the basis of published data, these two recently broken ends, derived from separate nuclei, are believed to be in the "unsaturated" state and therefore capable of fusion with each other. If some force exists that brings these unsaturated ends together and results in fusion, a dicentric chromosome should be produced composed of the chromosome 9 contributed by the female gamete and the chromosome 9 contributed by the male gamete, fused at the ends of their short arms. Through the use of the endosperm markers *I* and *C* and through the aberrant mitotic behavior

that reflects the presence of such broken chromosomes in the endosperm, it was possible to select the kernels from an ear whose zygote nucleus had received a chromosome with an unsaturated broken end from the male and female gamete nuclei, respectively.

Out of a total of 18,243 kernels examined, 20 non-germless kernels were obviously of the type desired. These kernels were germinated. If fusion had occurred between the broken ends of the chromosomes 9 contributed by the two gametes, following chromosome reduplication, the dicentric chromosome should produce a double anaphase bridge configuration when the two centromeres of each chromatid passed to opposite poles. Breakage of the two bridges would result in the entrance into each nucleus of two newly derived, unsaturated broken ends. Fusion of unsaturated broken ends could occur in each sister telophase nucleus. Again, the two chromosomes 9 would be joined to form one chromosome with two centromeres. Repeated anaphase bridge configurations should be expected to follow from such a chromosomal type of breakage-fusion-bridge cycle. Plants having such a dicentric chromosome and undergoing this cycle should have cells with various types of heterozygous and homozygous duplications and deficiencies of the short arm of chromosome 9 following nonmedian breakages of the anaphase bridges. Because of this process, the plants should be conspicuously modified in appearance. The plants arising from 10 of the 20 kernels were obviously of the type expected if a dicentric chromosome 9 were present. Examination of the early roots confirmed the presence of a dicentric chromosome. Some-

what less than one-half of the anaphase figures showed contiguous double bridges. Owing to death or defective growth of many cells or sectors of tissue, 5 of these plants died in the seedling stage. Four of the remaining 5 plants continued to grow, because sectors of normal-appearing tissues developed. Gradually these sectors gained the ascendancy in growth, until the plant appeared quite normal. The fifth plant produced 3 normal shoots, which arose from the base of the decidedly aberrant and dying main shoot. Microsporocytes were obtained from the 4 recovered plants and from 2 of the 3 recovered shoots of the fifth plant. In all cases, pachytene analysis showed a bivalent chromosome 9. The two chromosomes were not fused at the ends of their short arms. The two broken ends had healed in the ancestor cell which gave rise to the recovered sector. In most cases, the composition of the short arm of each member of the bivalent was greatly modified, although within a tassel sample all examined sporocytes showed the same composition for the individual member of the bivalent. In several of these plants, it was possible to determine the minimum number of fusions, breakages, and bridges which must have occurred before healing of the two broken ends within a single nucleus had occurred. It is likewise known that the compositions of the short arms were entirely different in the sporocytes of the tassels of the 3 recovered shoots of the one original dicentric plant. The two chromosomes 9, however, had maintained their respective derived compositions within each shoot. This indicates that the microsporocyte tissues of each shoot had originated from one individual cell whose cell ancestors had previously been undergoing the chromosomal type of breakage-fusion-bridge cycle involving the original dicentric chromosome 9. The root system

responded similarly. In the older roots of the surviving plants, no dicentric anaphase bridge configurations were observed.

These experiments definitely show the existence of an "unsaturated" state of a recently broken end of a chromosome. Owing to causes as yet undetermined, however, such an end may become saturated (healed) without fusion. Following this, the end no longer takes part in any fusions.

The remaining 10 of the original 20 kernels classified as having received a broken chromosome 9 from each parent gave rise to 9 normal-appearing plants and 1 pale-yellow plant which died in the seedling stage. None of these plants showed dicentric bridge configurations in the young roots. Examination of the sporocytes of the 9 surviving plants showed that 4 had received a broken chromosome 9 from each parent; but the morphology of the short arms gave no indication that fusions had occurred between these broken ends. In 1 plant one parent had contributed a broken chromosome 9, but it could not be determined whether the other parent had likewise contributed a broken chromosome 9. In the remaining 4 plants, each parent had contributed a broken chromosome 9, but one broken end had become saturated by fusion with a broken end other than that of the chromosome 9 contributed by the second gamete and possibly before fusion of the gametes themselves. Consequently, healing of the broken end of the second chromosome 9 had occurred. These results indicate that an unsaturated broken end produced by mechanical breakage of an anaphase bridge is capable of fusing with another unsaturated broken end arising from undetermined causes.

A similar type of fusion has likewise been observed in sporocytes of 5 plants which were known to have been derived

from a gametophyte which had received a chromosome 9 with an unsaturated broken end. It is known that mechanical pull caused by an anaphase bridge will frequently break a chromosome at a knob or at the centromere. In 2 of the 5 cases, the centromere of the broken chromosome 9 was fused with the centromere of another chromosome of the complement. In one case, the fused chromosome was composed of the long arm of chromosome 9 and the short arm of chromosome 2. In the second case, it was composed of the long arm of chromosome 9 and the short arm of chromosome 10. In each case, the complementary arm was missing. In three cases, the fusions had occurred at other positions than centromeres. In one case, a segment from the long arm of chromosome 4 had united with the broken end of the short arm of chromosome 9. Since both chromosomes 4 in this plant were completely normal, it is assumed that chromatid fusion in a gametophytic nucleus had occurred between the unsaturated broken end of chromosome 9 and a naturally arising broken end terminating an acentric distal segment of chromosome 4. In the other two cases, both segments of the second broken chromosome were present. Pachytene analysis has led to the following interpretation: In the last two cases mentioned, a break occurred at one position in chromosomes 1 and 8, respectively. In both cases, this resulted in the presence of three unsaturated broken ends in the same nucleus, one of which was the broken end of the short arm of chromosome 9. Fusion occurred between the unsaturated broken end of chromosome 9 and the unsaturated broken end of the acentric segment of the second broken chromosome. This left the centric segment of the second broken chromosome with a single unsaturated broken end, which thereafter healed. This healing of a single un-

saturated broken end, when introduced into sporophytic tissues, is in agreement with the results of similar investigations of this behavior.

PHENOTYPIC EFFECTS OF HOMOZYGOUS DEFICIENCIES OF DISTAL SEGMENTS OF THE SHORT ARM OF CHROMOSOME 9

The phenotypic effects in male gametophytes, and in endosperm and sporophytic tissues, of a series of homozygous deficiencies involving distal segments of the short arm of chromosome 9 are being investigated. These deficiencies were obtained through meiotic breakage of a dicentric chromatid 9 which had been produced following crossing over involving a duplicated segment of the short arm of chromosome 9. This method has been previously described (McClintock, 1941; see bibliography). A number of terminal deficiencies have been isolated, ranging in length from a fraction of the terminal chromomere to deficiencies of approximately one-third of the short arm, including the locus of *C*. At pachytene, the short arm of chromosome 9 has approximately 20 chromomeres. Those in the proximal third of the arm are large, those in the distal two-thirds of the arm are small.

The effect of homozygous deficiencies on the functioning of female gametophytes. Plants heterozygous for these deficiencies produce female gametophytes which are totally deficient for the respective segments of chromosome 9. Complete functioning of such gametophytes occurs in all cases of short deficiencies. Only in the case of longer deficiencies which include 4 or more chromomeres is there a reduction in the functioning of such gametophytes. Environmental factors may be involved in this differential functioning. A preliminary test has indicated that, on a single ear, functioning of deficient female

gametophytes may be complete on one day and they may be totally nonfunctional on the succeeding day. Extensive tests are necessary to associate the effect with a particular environmental condition.

The effect of homozygous deficiencies on the appearance and functioning of male gametophytes. Plants heterozygous for these terminal deficiencies produce pollen grains one-half of which carry the deficient chromosome 9. In all cases, homozygous deficient pollen grains are completely filled with starch. Only in the case of deficiencies that include the distal one-third of the short arm is it possible to distinguish any perceptible differences in the appearance of the normal and the homozygous deficient grains. The latter grains appear to be smaller, but an exact identification of each grain has not been possible. Only in the case of distal deficiencies that are greater than one-third of the short arm is there a classifiable visible effect on pollen development. Some starch develops even in pollen grains that are deficient for nearly all of the short arm of chromosome 9.

Pollen grains that are deficient for small terminal segments are completely functional. Those deficient for more than the terminal chromomere, although completely normal in appearance, are nonfunctional.

The phenotypic effects of small terminal deficiencies on endosperm and sporophytic tissues: the deficiency mutants "pale-yellow" and "white" and their dominance relationships. Plants that are heterozygous for small terminal deficiencies produce viable and functional male and female gametophytes. These plants were selfed to determine whether viable endosperms and embryos that were homozygous for these deficiencies could be obtained. In 5 of the 7 cases studied, the endosperm and embryo of kernels having the homozygous deficiencies were completely normal in ap-

pearance. In 2 cases, some but not all of the embryos that were homozygous deficient had died before the maturity of the kernel. The endosperm of these kernels, however, was completely normal. In all 5 cases with normal embryo development, pale-yellow seedlings, completely normal in gross morphology and growth rate, grew from these kernels. Although the coleoptiles were light green, little chlorophyll developed in the leaves, and the seedlings died after exhaustion of the food reserves in the endosperm. The surviving embryos in the 2 cases where the homozygous deficiency resulted in early death of some embryos produced white seedlings completely devoid of plastid pigments. Although the gross morphology of these seedlings was normal, the growth rate was considerably retarded. Proof of the association of the pale-yellow and white seedlings with the homozygous deficient state was obtained through cytological examination of normal sibs, which had only homozygous normal and heterozygous deficient chromosomes; through crosses of these latter plants to plants heterozygous for longer deficiencies, where the mutant types appeared only from unions of the two respective deficient chromosomes; through close if not complete linkage with the mutant *yg* located near the end of the short arm of chromosome 9; and through chromosomal examination within white sectors of sectorial plants.

Intercrosses among all 7 cases have shown that the 5 pale-yellow mutants are allelic and that the 2 white-seedling mutants are allelic to pale-yellow, with pale-yellow dominant to white. The 5 deficiencies giving rise to pale-yellow do not include the *yg* locus, whereas the 2 deficiencies giving rise to white seedlings may include this locus. The deficiencies giving rise to white seedlings are longer than those giving rise to pale-yellow seedlings,

although they have a deficient segment in common. This accounts for the allelic nature of the two mutants and the dominance of pale-yellow over white. The pale-yellow and white mutants represent typical Mendelizing mutants, which are associated with a state of homozygous deficiency. Dominance in these cases is an expression of the extent of the deficiency: no deficiency produces green seedlings, a short terminal deficiency produces pale-yellow seedlings, and a longer terminal deficiency produces white seedlings, with dominance expressed in this order.

The phenotypic effects of relatively long terminal homozygous deficiencies. Terminal deficiencies that include more than one chromomere do not give rise to functional pollen. Thus, the phenotypic effects of these deficiencies could not be studied by the direct method of selfing heterozygous plants. Instead, the variegation method, which produces sectors of tissue that are homozygous deficient, was introduced in these cases. This method utilizes the aberrant mitotic behavior of recently broken chromosomes, which, in the endosperm, continuously deletes segments from the arm of the chromosome which has the broken end. If the female gametophyte contributed 2 deficient chromosomes, and the male gametophyte contributed a chromosome 9 whose short arm terminated in a recently broken end, the developing endosperm could be sectorial for homozygous deficient tissues. The endosperm mutants *C* (aleurone color), *I* (inhibitor of aleurone color, allelic and dominant to *C*), *Sh* (*sh*, shrunken endosperm), and *Wx* (*wx*, waxy starch) were used to mark the chromosomes contributed by the two parents. The preliminary investigations on the effects of homozygous deficiencies on endosperm development may be summarized as follows: Endosperm development may be completely normal when homozy-

gous deficiencies up to and including two terminal chromomeres are present. Beyond this region, only patches of such homozygous deficient tissue, surrounded by normal tissues, will develop. As the homozygous deficiency becomes progressively longer, the rate of development within the sector is reduced. Although the *C* locus may still be present, aleurone-color development progressively diminishes until only the rim of cells bordering normal cells shows color. Apparently, some substance or substances diffuse from the normal cells into these homozygous deficient cells, allowing them to develop normal aleurone color. This material, however, either does not diffuse beyond a layer several cells deep or is used up before deeper penetration occurs. Starch development occurs in all the patches of homozygous deficient cells except when the deficiency approaches the distal third of the short arm and includes the locus of *C*. In the latter case, relatively extensive growth of the homozygous deficient cells occurs; but, owing to lack of starch formation in these cells, a shrinkage leading to scar formation occurs after drying of the kernels.

To study the effects of various homozygous deficiencies on sporophytic tissues, the method of covering a deficiency with a ring-shaped chromosome may be utilized. Frequent losses of the ring-shaped chromosome during mitoses should produce cells that are homozygous deficient. Cells arising from these cells should produce sectors capable of expressing changes that could be related to the homozygous deficient state. Likewise, changes in constitution of ring chromosomes, which may delete segments from the ring, could produce sectors that are homozygous deficient for various segments within the limits of the full deficiency. Only two such plants

have been produced. Both plants were characterized by numerous sectors of white, pale-yellow, and yellow-green tissues. Although these sectors probably represent the expression of homozygous deficiencies, no conclusions will be drawn until this method receives more detailed and controlled analysis.

A deficiency of one-third of the short arm of chromosome 9 is relatively long,

but none of these deficiencies have been cell lethal in any of the tissues studied. It is altogether possible that the observed effects of the homozygous deficiencies in the various tissues may be related to a few specific loci within the limits of the distal third of the short arm, rather than to the accumulative effect of a large number of such loci. This would be understandable if maize were a derived polyploid.

POLYPLOIDY INVESTIGATIONS

H. E. WARMKE

THE MARIHUANA CONTENT OF HEMP

In addition to producing valuable fiber, hemp (*Cannabis sativa*) also produces the undesirable drug marihuana. With the huge plantings of this species throughout the nation necessitated by the interruption of fiber shipments from abroad, the problem of control of this drug threatens to become a difficult one. For this reason, Drs. Barre and Robinson, of the Division of Cotton and Other Fiber Crops, Bureau of Plant Industry, U. S. Department of Agriculture, suggested that the Department of Genetics help on a project started by them some time ago: that of producing a strain of hemp with materially reduced marihuana content, if such is possible, by methods of selection and breeding.

Several superior fiber strains were supplied, and have been tested for drug content during the past season, using a modification of the bio-assay method of Robinson (1941). This method, as modified by the present workers, is based on the toxicity to the fish *Fundulus heteroclitus* of different dilutions of acetone extracts of weighed samples of dry leaves, and has proved to be a completely practical method of marihuana assay. A series of four decreasing dilutions, each containing 2 fish, is used to test each plant; and records are

kept of the number of fish killed, the limits being 0 fish killed for plants with low drug content and 8 fish killed for plants with extremely high drug content. Such an assay, of course, does not give absolute concentrations, but it does provide an estimate of the relative amounts of drug present in the series of plants being tested.

Over 1000 marihuana determinations have been run during the course of the summer; results of tests on some 258 plants are given graphically in figure 1. It is of interest that the plants tested, although growing under as nearly identical conditions as possible, vary widely in marihuana content. For example, 10 plants were found whose extracts failed to kill a single fish, even in the strongest concentration, and 1 plant was found which killed fish through all concentrations, including the most dilute.

On the basis of dilutions used, this would represent an eightfold range in marihuana content, and is extremely encouraging as a starting point for selection and breeding experiments. If these differences are largely genetically controlled, by intercrossing the plants on the left of figure 1 we should expect to obtain races in subsequent generations with greatly reduced average marihuana content. Of course, marihuana

content is thought to be influenced by both genetic and environmental factors, and only further tests can show which of these factors is predominant in producing the array of potencies represented in figure 1.

The data in figure 1 were regrouped so as to give a comparison of marihuana content of male and female plants. The 116 females represented in this array killed an average of 3.5 fish per test, and the 86

ing called attention to the necessity of exercising caution in taking leaf samples for marihuana determinations, and eventually led to the adoption of a method using the center leaflet from each leaf on the plant, rather than selected whole leaves as had been done previously.

POLYPLOIDY AND MARIHUANA CONTENT

Marihuana determinations were also run on our original autopolyploid races of hemp in order to determine whether alkaloid content is affected by increase in chromosome number. These polyploid races, although not inbred, were all derived from the same original diploid strain, and therefore have a comparable genetic background.

The results of these tests, based on determinations from 25 plants for each member of the series, are as follows:

Polyloid	Average no. fish killed
Diploid	1.4
Triploid	3.0
Tetraploid	2.6

This indicates a definite increase in marihuana content in the triploid and tetraploid races, which of course could not have been predicted in advance.

A similar increase in vitamin C content in autotetraploid tomatoes has been reported by Sansome and Zilva (1933); and Randolph and Hand have recently found an increased concentration of vitamin A in autotetraploid corn. Cases of this nature, where the autopolyploid produces a chemical product in a different concentration from its related diploid, are beginning to be noted; these throw important light on the mechanism of gene balance and action.

The slightly greater drug content in triploids than in tetraploids in these tests

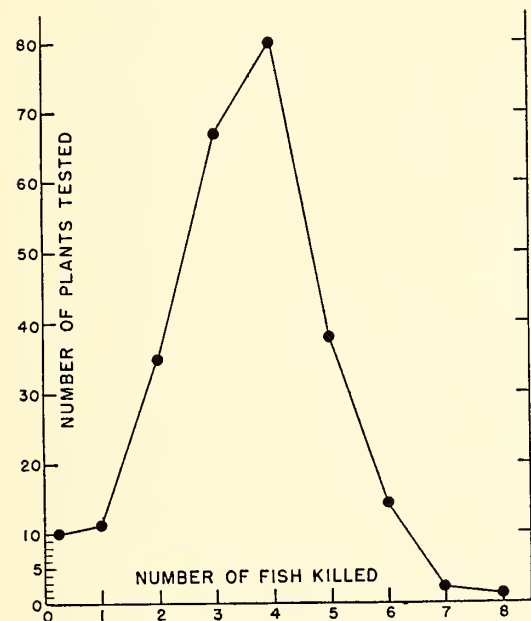


FIG. 1. Relative marihuana concentrations in 258 hemp plants as indicated by toxicity to fish of acetone extracts of dry leaves. Zero fish killed indicates plant with low toxicity; 8 fish killed indicates plant with high toxicity.

males killed an average of 3.7 fish. These differences probably are not significant, and confirm the conclusions from previous limited chemical tests (Matchett and others, 1940) that no important sex difference in marihuana content exists.

Tests of single entire hemp leaves have shown an unmistakable gradient in alkaloid content extending from bottom to top of the plant. The bottom leaves have an extremely low alkaloid concentration, the top leaves a very high one. This find-

is out of line in the polyploid series. Whether this difference will be borne out with more extensive testing is not known; it was found consistently, however, among the plants in this series of tests.

Before these marihuana determinations on polyploids were made, samples of seed of our established diploid and tetraploid races had been submitted to the Department of Agriculture for comparative tests of fiber quality and quantity. The robust habit of the tetraploid had suggested a possible superiority in fiber content. It would now appear that the tetraploid race will be less desirable than the diploid from the standpoint of drug content; final judgment on its over-all value, however, must await the results of the fiber tests now in progress.

THE RUSSIAN DANDELION

In May 1942, Dr. E. W. Brandes, in charge of special rubber investigations of the Bureau of Plant Industry, requested the Department to undertake a cytogenetic study of the rubber-bearing Russian dandelion (*Taraxacum kōk-saghyz*). The purpose of the investigation was to ascertain the chromosome number and reproductive behavior, in order to lay a foundation for the intelligent growing and breeding of this species in America. Some 2000 plants have been grown in the greenhouses and out of doors during the past season. A sufficient number of these have come into flower so that certain findings can be reported at this time. These findings generally are in agreement with those of the Russian workers Poddubnaja-Arnoldi and Dianowa.

Taraxacum kōk-saghyz is a basic diploid in the genus, with a chromosome number of $n = 8$; $2n = 16$, at least one pair of which bear satellites. Those plants that have reached the flowering stage to date fail to

set seed when isolated in the greenhouses, but set seed abundantly out of doors or when manually cross-pollinated in the greenhouse. This indicates the species to be self-sterile, but fully cross-fertile.

Studies now in progress indicate that gamete formation is normal on both the male and female sides. The formation of the female gamete, which is often abnormal in the common species of dandelion, leading to the parthenogenetic development of an unreduced egg cell, appears to follow the normal sexual pattern in *T. kōk-saghyz*. The archesporial cell enlarges and undergoes a normal meiosis to form a linear series of 4 reduced megaspores, the chalazal one of which develops into a normal 8-celled embryo sac.

These conditions are extremely fortunate from a practical point of view, because they make selecting and breeding experiments possible. Since *T. kōk-saghyz* is a member of the Compositae, experimental breeding would have been extremely difficult had it proved self-fertile or parthenogenetic.

Several hundred colchicine-treated plants are also being grown in an effort to obtain a tetraploid race. On the chance that the tetraploid might show altered, and possibly desirable, rubber-producing qualities, it seemed of value to treat a group of plants. Many of these have been markedly affected by the treatment, as indicated by rough and thick leaves. Pollen-size determinations of four treated plants that are now in flower show one to be tetraploid; so it is hoped that a tetraploid race may be established sometime this winter.

THE SEX MECHANISM IN *SILENE OTITES*

Silene otites is a dioecious plant, but whether the male or female is heterogametic (XY) cannot be determined by cy-

tological methods, because of similarity in size of the sex chromosomes. Sansome (1938) has reported the female to be heterogametic on the basis of indirect evidence obtained from interspecific hybrids. By doubling the chromosome number in this species and utilizing the peculiar breeding behavior of the $4n$ sex heterozygote, it has been possible to present extremely good evidence to the contrary: that the male is XY.

The method is as follows: Using colchicine, XX and XY plants are transformed into XXXX and XXYY plants, respectively. The XXXX individuals will produce only XX gametes, but the XXYY individuals will produce at least 1 XX:4 XY:1 YY gametes. A higher proportion of XY gametes will result if differentiation of the sex chromosomes is sufficient to disturb random pairing. When XXXX and XXYY individuals are crossed, therefore, three types of offspring are expected: 1 XXXX:4 XXXY:1 XXYY. In *Silene*, approximately 5 males to 1 female are obtained when treated $4n$ males and females are crossed, which indicates two classes of males: 1 XXYY and 4 XXXY, or 1 XXXX and 4 XXXY, depending upon whether the female is XXXX or XXYY. To determine the constitution of the female, several of the treated $4n$ females are crossed to diploid males (and reciprocal if possible). If the female is XXXX, a $3n$ population of 1 male to 1 female should result; if it is XXYY, 5 males to 1 female would be expected. In *Silene* this cross has produced triploid males and females in a ratio that does not deviate significantly from 1:1. This indicates that females are

homogametic and males are heterogametic, and makes possible the interpretation of breeding results on the same basis as in *Melandrium*.

Further evidence is being sought by intercrossing tetraploid males and females from 1:1 pedigrees. If the above explanation is correct, these should give only 1:1 populations; if it is incorrect, ratios other than 1:1 should be observed. It seems likely that these methods may find wide application in determining the heterogametic sex in species other than *S. otites*.

A GYNODIOECIOUS RACE IN MELANDRIUM

One of the results of the inbreeding program being carried on with *Melandrium* (Year Books Nos. 39 and 40) is the establishment of a diploid race consisting of XX females and XY male-hermaphrodites. This race arose by the recovery of XX and XY types from the self of selected strongly female XXY types.

When these XX and XY types are crossed, females and male-hermaphrodites appear in approximately a 1:1 ratio. The XY male-hermaphrodites, when selfed, produce females and male-hermaphrodites in the ratio of approximately 1:3 (10:33). The securing of selfed offspring from the XY plants was of extreme interest because it afforded an opportunity to obtain YY individuals, a type reported in some other species but never in *Melandrium*. The cytological analysis of 26 of the male types from these pedigrees, however, has shown only plants with X and Y chromosomes, which probably indicates the YY type to be inviable.

THE GENE

M. DEMEREC, B. P. KAUFMANN, U. FANO, EILEEN SUTTON, AND EVA R. SANSOME

GENE POSITION AND ACTION

A gene increasing mutability. It was noted in various experiments conducted by Dr. Demerec that X-chromosome lethals originated with much higher frequency in certain males from the wild-type Swedish-b stock than in their brothers. Further tests indicated that such males contain a gene that increases the rate of mutability of other genes. Experiments are now under way to isolate this gene and to study its behavior. It appears that this mutability gene is similar to the one found earlier in the wild-type Florida stock and described in Year Book No. 35 (1935-1936), pages 43-45.

Semisterility genes in Drosophila. Attempts to investigate and reduce the sterility of untreated *Drosophila* material, in order to improve the conditions for accurate measurement of dominant lethals, were reported in Year Book No. 40 by Dr. Fano. These attempts resulted in the isolation from Swedish-b stock of a new recessive semisterility character, located in the second chromosome and effective only in females. A majority of the eggs laid by females that are semisterile (*sst*) fails to hatch. Counts of the offspring of 27 *sst* females showed that the proportion of eggs hatching varied between 12 per cent and 52 per cent. Genetic characters inducing complete sterility have frequently been reported in the literature, but the new character described here seems to belong to a less well recognized type. It might have been expected that the constitutional characteristics of a female affecting the degree of viability of its offspring would be determined by the collective action of a large number of factors, each of them only slightly important in itself. The identifica-

tion of the factor *sst* indicates that this is not so. This one character brings about very striking effects; but the experiments indicate that weaker characters having analogous effects are so widespread among laboratory stocks as to make it difficult to isolate high-fertility strains.

Cytogenetic analysis of the Bar locus. The analysis of our stocks of Bar, double-Bar, and double infra-Bar confirmed Bridges' (1935) cytological analysis of the first two, and showed no detectable difference between double-Bar and double infra-Bar.

Twenty-nine changes at the Bar locus (changes from wild-type to Bar, from Bar to or toward wild-type, and from double-Bar and double infra-Bar to or toward wild-type) have been analyzed cytologically and genetically by Dr. Sutton.

The Bar locus appears to be associated with the band 16A1·2 of the salivary-gland X chromosome, and the Bar phenotype is produced by a limited number of the possible rearrangements in which this locus is brought into immediate contact with loci in other parts of the chromosomes. The Bar effect is thus a position effect, and is not essentially different from other known position effects. In no case has the Bar effect been produced by mutation of the Bar locus without rearrangement, but reversions of Bar to normal can be brought about by mutation or inactivation of the Bar locus or the adjacent interacting locus. In the original Bar stock the position effect seems to be produced by the contiguity of the bands 16A1·2 and 16A7, and in double-Bar and double infra-Bar this association of bands is duplicated. Complete reversions of double-Bar or double infra-Bar to wild-type have been

obtained by irradiation, without any visible change in the chromosomes, and these phenotypic changes must be due to simultaneous inactivation of both associations of the interacting loci.

Location of genes in the salivary-gland X chromosome. Over a period of eight years, all spontaneous and induced changes obtained in loci in the X chromosome have been analyzed both genetically and cytologically. The genetic tests determined all loci affected in each case, and the cytological analysis of salivary-gland chromosomes determined what chromosomal aberrations, if any, were associated with the genetic changes. The accumulated data have made it possible to correlate particular genes with single bands or strictly delimited regions of the salivary-gland X chromosome. The following genes have been located in this way: *y* and *ac* (1A5-8), *sc* (1B3-4), *svr* (1B5,6), *M(1)Bld* (1B11-1C2-3), *sta*, *tw*, and *br* (1C4-5-2C10), *pn* (2D5,6), *kz* (2E1-2-2F6), *w* (3C2-3), *rst* (3C4), *N* (3C7), *dm* (3D1-2), *M(1)3E* (3E3-4), *ec* (3F1-2), *M(1)4BC* (4B5-4C5-6), *bi*, *peb*, and *rb* (4C7-8-4D1-2), *rg* (4E1-3), *cx* and *cv* (4F1-2-5D1-2), *rux* and *vs* (5D3-4-6A1-2), *dx*, *shf*, *scp*, and *cm* (6A3-4-6F10-11), *ct* (7B3,4), *sn*, *oc*, *ptg*, *dd*, *tbd*, and *con* (7C4-5-8C1-2), *t* and *lz* (8C3-17), *dvr* (to right of 8D8-9), *m* (10C3-4-E1-2), *dy* (to right of 10E1-2), *M(1)o* (15B1-2-E7), *f* (15F1-5), *B* (16A1-2).

Mutants of Drosophila melanogaster. The compilation of descriptions of the mutants of *Drosophila melanogaster* made by Dr. C. B. Bridges and printed in first draft in 1938 as *Drosophila Information Service* No. 9 has been completed and edited by Dr. Katherine S. Brehme, and is to be entitled "The mutants of *Drosophila melanogaster*." In preparing the first draft, Dr. Bridges utilized the mutation list which he had maintained and continually revised

since 1914, and which included the data concerning all significant mutations and reoccurrences found by him and other members of the laboratory of Dr. T. H. Morgan. He also used the information published in the Carnegie monographs and in *Drosophila Information Service* Nos. 1-8. Special contributions of new data were made by a number of investigators. After the death of Dr. Bridges, a systematic survey of the literature was made by Dr. Brehme, covering all available publications on the genetics of *Drosophila* through August 1942. An attempt was made to include such information concerning the mutations as would be of use to investigators, and to document all data as thoroughly as possible. Each person responsible for the original description of a mutant was consulted concerning the accuracy of the description included in the volume, and was asked to contribute new data. In this part of the work, fifty-eight investigators were generous contributors and consultants. Many of the illustrations used in the volume are the work of Miss Edith M. Wallace; some of her drawings are here published for the first time, and some are republished. Other illustrations are reprinted from the publications of many workers, and have been redrawn by Miss Alice Hellmer or photographed by Miss Ruby Gay Stewartson. The finished manuscript was critically read as a whole by Drs. M. Demerec, T. H. Morgan, J. Schultz, C. Stern, and A. H. Sturtevant, and in part by several other authorities; and their suggestions have, so far as possible, been faithfully carried out.

Ultraviolet absorption in the salivary-gland chromosomes of mottled phenotypes. The work on ultraviolet absorption (see *Year Book* No. 40) has been continued by Dr. P. A. Cole and Dr. Sutton at the National Institute of Health, Bethesda, Maryland. One of the aims of this work

was to investigate a possible correlation between phenotypic variegation, due to translocation of genes to heterochromatin, and the variation in absorption of ultraviolet by the bands with which these genes are associated. Larvae of two genotypes were used, one of which ($w^{mot} 258-21/y\ sc\ w; Cy/+$) shows rather slight variegation of the adult eye at 18°C ., associated with an X-4 translocation. The other type ($w^{mot} 258-21/y\ sc\ w; Ms10/+$) has the same translocation together with a second-chromosome modifier which increases the phenotypic variegation so that the eye is largely white, with a few small flecks of red facets. A set of ultraviolet photomicrographs was made from larvae of each type. If there is a close correlation between the nucleic acid content of the bands and the degree of phenotypic variegation, a comparison of absorption by the normal and translocated bands in each set of photographs should show a significant difference between the two sets.

Analysis of the data is now in progress. Inspection of the plates by eye does not reveal any marked difference between the two sets. Measurements of the plates have been made by means of a recording microphotometer in the laboratory of Dr. I. Gersh, Department of Anatomy, Johns Hopkins Medical School, Baltimore, and the calculation of extinction coefficients from these measurements is now in progress.

Experiments with heavy water (deuterium oxide). Dr. Stephen Zamenhof and Dr. Demerec conducted a series of experiments in which one generation of *Drosophila* was raised on food containing either 40 per cent or 55 per cent of heavy water. The males thus obtained were tested for X-chromosome lethals by the standard CLB method. It is known that if water containing deuterium reaches an

organic compound, hydrogens that are connected with N and O exchange with the deuterium almost instantly, in a ratio corresponding to the deuterium/hydrogen ratio in the surrounding water. This exchange is easily reversible, and if pure water subsequently reaches this compound all the deuterium is replaced again by hydrogen. Thus, in the present experiment it is estimated that the genes contained up to 30 per cent of C-connected deuterium and up to 40 per cent of N- and O-connected deuterium in place of hydrogen. Tests made on about 2000 treated sperms showed no increase in the frequency of lethals in treated flies as compared with controls. There are at least two possible explanations of these results. One is that the substitution of deuterium for hydrogen did not change either the structure or the activity of the gene; another possibility is that the gene structure did change, but was able to return to its original form as soon as deuterium was replaced by hydrogen.

CHROMOSOME BREAKAGE AND RECOMBINATION

Chromosomal rearrangements in *Drosophila* may be induced by X-ray treatment of spermatozoa of the adult male. As was reported in Year Book No. 39, evidence has been collected which indicates that although the potential breaks are induced in the mature sperm, new combinations of chromosomes do not arise until after the sperm nucleus has penetrated the egg. Since the interval between irradiation of the sperms and their utilization in fertilization can be extended over many days without the occurrence of break recombination or restitution, an opportunity is offered to attempt to alter these phenomena experimentally. Ability to alter the customary behavior of the X-ray-

sensitized regions might throw some light on the nature of the disturbances produced in the chromosomes by irradiation.

Presumably the chromosomes, following X radiation, are in a highly "labile" state, and in this condition may be sensitive to types of treatment that leave no imprint on the genetic constitution of the normal cell. Supplementary energy necessary to affect the regions of potential breakage might conceivably be supplied either by chemical or by physical agents. Use of the former seems less desirable because of the difficulty of securing penetration into the nucleus without impairing or destroying the vital functions of the cell. An approach offering more promise of success is the use of radiant energy.

In line with these considerations, a series of experiments have been designed by Drs. Kaufmann and Hollaender to measure the effects of several wave lengths in the near infrared and ultraviolet portions of the spectrum. So far as is known from a series of control experiments, neither of these agents is in itself instrumental in causing gross chromosomal derangements. The near infrared rays can be produced quite readily in high intensities, they are absorbed only slightly by water, and they penetrate well into living tissues. Rays in the range between 8000 and 15,000 Å, obtained from a high-intensity source, have been concentrated on the *Drosophila* males, which were retained in a glass vial surrounded by a cooling coil. Results of these first experiments indicate that with increasing exposure to the infrared there is a decrease in the frequency both of altered sperms and of chromosomal breaks, as measured by cytological analysis of the F₁ salivary glands of larval descendants of irradiated fathers. Thus, in one set of experiments in which 2000 roentgens of X rays were given, followed by infrared

and then another 2000 r, these values were obtained:

Hours infrared	% altered sperms	% breaks
72.....	26.7	66.4
144.....	20.9	58.9
216.....	14.1	32.1

Control values for 4000 r (given in either single or fraction treatments) are about 30 per cent altered sperms and 86 per cent breaks.

Within the ultraviolet portion of the spectrum, the wave length 2537 Å has been tested. Radiation of this type is most fully absorbed by the nucleic acid component of the chromosomes. Males exposed to a combined treatment of 4000 r plus the ultraviolet also gave much lower values than the X-ray controls, namely, 14.5 per cent altered sperms and 36.3 per cent breaks.

Since these are only preliminary experiments, full appraisal of the physical and biological factors involved must await the compilation of additional data, including a more complete set of controls. One possible explanation of the results is that the supplementary radiation serves to accelerate the process of repair or restitution that occurs naturally in some of the potential breaks induced by X radiation.

The frequency with which such natural restitution occurs has been given further consideration by Dr. Fano. In Year Books Nos. 39 and 40, attention was directed to some theoretical and experimental approaches to the correlation of data on chromosomal changes, obtained by observations of dominant lethals and other cytogenetic techniques. It had been found that most of the lethals produced by low dosages of X rays behave as if they were due to single-break processes. Certain difficulties, which at that time seemed to prevent full acceptance of this hypothesis,

have now been removed by the work of G. Pontecorvo, of the University of Edinburgh. We may thus accept the conclusion based on our data that single breaks are produced in *Drosophila* sperms at a rate of about 15 per cent per 1000 r of X rays. It is, however, not immediately clear whether most of the cases with a single breakage result in dominant lethals, or whether many of the single breaks "heal," thus to become completely obliterated. Data collected by other authors on different materials indicate that the second alternative obtains; and the following considerations applying to *Drosophila* point in the same direction.

If no other breakages were available than those detected by dominant-lethal counts, and assuming that individual breakages occur independently of one another, the frequencies of the occurrence of different numbers of breaks in the same sperm should follow a Poisson distribution. Accordingly, the expected frequency of sperms with two breaks at 1000 r ought to be approximately $\frac{1}{2}(0.15)^2 \approx 1\%$. This figure is far too low to account for the frequency ($\approx 3\%$) of viable two-break rearrangements, so that we may conclude that the average frequency of potential or actual breakages at 1000 r considerably exceeds 15 per cent.

The number of points of potential breakage induced within a single nucleus may also be much greater than had been anticipated on the basis of the complexity of previously observed rearrangements. In earlier experiments a 14-break case had been analyzed; in the course of the studies combining X rays with the near infrared, a rearrangement was found by Kaufmann which involved at least 32 points of breakage. The positions of 30 of these breaks have been determined; others restricted to the proximal heterochromatin remain of uncertain location. Distribution of identi-

fiable breakage points among the chromosomes is as follows: 6 in the X chromosome, 3 in the left limb of the second chromosome (2L), 5 in 2R, 3 in 3L, 12 in 3R, 1 in the fourth chromosome. Aside from its great complexity, this rearrangement is particularly interesting because of the accumulation of breaks in the right limb of the third chromosome. The probability of such a distribution on a chance basis is very small (between 0.02 and 0.05 on the basis of the χ^2 test). In the light of this finding, our other data on complex rearrangements are being examined more fully in an effort to secure additional information concerning the nature of the breakage-recombination phenomenon.

Another pair of glands analyzed in these studies illustrates the ability of two sister strands obtained from an irradiated chromosome to recombine independently of each other. These glands consisted of a mosaic of tissue containing two types of nuclei. One showed a mutual exchange between the 2R, 3L, and 3R chromosome limbs to give the following sequence of parts:

2L tip.....centromere.....60D/79Btip 3L
3R tip...98D/79B....centromere...98D/60D...tip 2R

The remaining nuclei revealed a reciprocal translocation of the following type:

2L tip.....centromere.....60D/79Btip 3L
2R tip..60D/79B.....centromeretip 3R

Although the two patterns of recombination differ with respect to the participation of the right limb of the third chromosome, the sequence of events responsible for this condition must remain, as in other similar cases, open to various interpretations. If it is assumed that the chromosomes of the irradiated sperm are unsplit and that all regions of potential breakage are duplicated in the derived sister chromatids, we must further postulate that

restitution has occurred in one of the 3R strands. On the other hand, we cannot eliminate the possibility that the chromosomes of the sperm are already split longitudinally and that sister strands may respond either identically or independently within the same nucleus.

NEUTRON EXPERIMENTS

Two peculiar facts have been reported in the literature concerning the distribution of neutron-induced recessive sex-linked lethals in *Drosophila*. Nagai and Locher have reported a nonrandom distribution of lethals among the sperms of different males. Nishina and Moriwaki have reported nonrandom distribution among sperms belonging to the same male. An experiment made by Dr. Fano was designed to check these unexpected findings. This experiment offered also an opportunity to examine several aspects of the comparative effects of X rays and neutrons, i.e.: (a) how frequently lethals are connected with cytologically detectable minute deficiencies, (b) how frequently lethals are connected with cytologically detectable gross chromosomal aberrations, (c) the relative frequency of recessive and dominant lethals.

Wild-type *Drosophila* males were treated with approximately 600 and 1200 units neutrons, measured with a standard 25-r Victoreen r-meter, and mated partly to ClB virgin females, partly to wild-type virgin females. The treatment was kindly supplied by the Columbia University cyclotron group, under the direction of Dr. J. R. Dunning. Dominant-lethal counts were made on F₁ offspring from wild-type females. F₁ ClB females from ClB parent females were mated singly to their *ec ct⁶ v g²* brothers and tested for recessive lethals. The maleless F₂ cultures—that is, those carrying a lethal—were further tested

by mating the wild-type females with *ec ct⁶ v g²* males. F₃ cultures were raised for 62 lethals, to determine the location of the lethal and to obtain salivary-gland cytological preparations.

The dominant-lethal counts have been completed, and show the following results, which are in fair agreement with those of Dempster: The fraction of adults hatching from eggs fertilized by treated sperm was 90 per cent for the controls, 27 per cent for the 600-unit treatment, and 4 per cent for the 1200-unit treatment. According to results reported in Year Book No. 40, it takes respectively about 3000 and 6000 r of X rays to produce the same effect. Assuming that 1 unit neutrons is energetically equivalent to about 2.5 r X rays, it takes about twice as much X-ray energy as neutron energy to produce the same dominant-lethal effect. This factor of 2 is larger than that (1.5) found by Dempster, but the two results are not strictly comparable because Dempster investigated the dosage necessary to induce 50 per cent lethality, instead of 73 per cent or 96 per cent as in the present experiments.

The investigation of the recessive lethals is still in progress, and only tentative results can be indicated. The distribution of lethals does not seem to depart from randomness—a result at variance with the results both of Nagai and Locher and of Nishina and Moriwaki. No lethal has yet been found cytologically to be connected with a deficiency. A large percentage of the lethals (about one-third) seems to be connected with chromosomal rearrangements. This result deviates from the findings on X-ray-induced lethals, but is not unexpected, because the ratio of the frequency of gross chromosomal changes to that of gene mutations is generally higher in neutron-treated than in X-rayed material. The over-all frequency of re-

cessive lethals per unit dose of energy absorbed from radiation has been found to be lower in neutron-treated than in X-rayed material, in agreement with the findings of Timofeef-Ressovsky and Zimmer, already confirmed by Demerec, Kaufmann, and Sutton.

Since neutrons are less efficient than X rays in producing sex-linked recessive lethals in *Drosophila*, when equal amounts of radiation energy are absorbed, Dr. Fano was interested in investigating the theoretical information that can be derived from this comparison. A detailed theory of this phenomenon was developed by Lea, which led to the evaluation of certain important quantities relating to gene structure. Since, however, this theory involved certain very special assumptions, an effort was directed toward estimating its actual significance.

If the production of ionizations along the paths of particles traversing tissue were extremely dense, it is conceivable that all particles passing close enough to the point where a mutation might occur would actually produce it. Under these conditions, the experimental rate of production of mutations would yield a measurement of the cross section of the "sensitive region" which represents the "target" to be "hit" by the particles. This sensitive region may have some significant connection with genetic structures; and therefore the evaluation of its cross section represents a desirable goal. As a matter of fact, no available radiation produces such a high density of ionizations as to fulfill the conditions described above. The theory developed by Lea, however, permits an extrapolation from the data available on the action of neutrons to the ideal case of infinitely dense ionization.

It has been found that this theory is subject to the following criticism: The hypotheses underlying it were selected as

the simplest schema fitting the present knowledge; the factors necessarily neglected might have been expected to average out, so that the results would be approximately correct. On the contrary, it turns out that all the neglected factors act in the same direction, so that the corresponding deviations from Lea's theoretical law add up instead of canceling out. Consequently, Lea's estimate of the cross section of the sensitive region, which is based on an extrapolation, is certainly in error by defect, by an undetermined amount which may conceivably be very large.

RADIATION EXPERIMENTS IN *NEUROSPORA*

It has been found by Hollaender and Emmons, working with *Fungi Imperfecti*, that fungi afford suitable material for studying the effect of ultraviolet radiation in producing mutations. The changes produced in *Fungi Imperfecti* could not be subjected to genetical test, however, and it was thought advisable to extend the study to a fungus in which the changes could be tested by being passed through a sexual stage. The ascomycete *Neurospora crassa* was finally chosen as the best available plant for this purpose, for several reasons. The life history of this fungus has been studied in detail by Dodge, who found it to be heterothallic and its sexual reproduction to be subject to experimental control. Lindegren and others have investigated its inheritance and found that Mendelian segregation occurs in the young ascus. Moreover, *Neurospora crassa* produces under certain reproducible conditions a special type of spores, "microconidia" or "spermatia." These spores, by virtue of their small size, uniformity, and probable uninucleate condition, afford favorable material for radiation experiments, as has been demonstrated by Lindegren.

This is a cooperative experiment with the National Institute of Health, in which Dr. M. Demerec, Dr. A. Hollaender, Mrs. M. Houlahan, and Mrs. Eva Sansome are taking part. The ultraviolet experiments are being performed by Hollaender and Houlahan at Bethesda, Maryland, and the X-ray experiments at Cold Spring Harbor; but every effort is being made to keep the conditions of the experiments as nearly comparable as possible.

Microconidia are obtained from the mutant strain *fluffy*, which does not form macroconidia. Fluffy cultures that are not more than three weeks removed from a single-spore (ascospore or microconidium) stage are used, in order to lessen the chance of irradiating spores from a culture that has become heterokaryotic by spontaneous mutation. The spores are extracted in salt solution, filtered through cotton under sterile conditions, centrifuged, and treated in suspension in salt solution. For the X-ray experiment a concentrated suspension of spores in a small vial holding about 1 cc. of suspension is irradiated. Samples of 0.1 cc. are taken for the control and for the different dosages given. Increase in dosage is obtained by increasing the time of exposure. In order to keep the selection of mutants as constant as possible, only the more distinct types are scored as mutants.

As a control on the ultraviolet experiments, 577 untreated spores were isolated, of which 1 was a mutant. In the X-ray experiment, 1 mutant was obtained from 521 untreated spore cultures. The spontaneous mutation rate, therefore, is low, and so far has been of a similar intensity in the Bethesda and Cold Spring Harbor cultures.

In the ultraviolet experiments the wave lengths tested, arranged in order of effectiveness in producing mutation, are 2650, 2537, 2480, 2805, 2380, 2967, 2280 Å.

An average of 4.7 per cent of mutations has been recorded for treatments at 2650, the highest recorded rate being 13 per cent. Nucleic acid has maximum absorption in this region of the spectrum.

In the X-ray experiments a wave length of about 0.3 Å was used and dosages of 2250, 4500, 9000, 13,500, 18,000, and 22,500 r units have been given. The preliminary results indicate a linear increase in mutation rate up to the highest dosage given, as shown below:

Dosage	% mutations among survivors
2,250.....	1
4,500.....	3
9,000.....	5.5
13,500.....	9.8
18,000.....	10
22,500.....	14

There seems to be some evidence that the X-ray treatment at these dosages stimulates the germination of the microconidia. This makes it difficult to detect killing effects of low magnitude. It is reasonably certain, however, that up to 22,500 r units the survival ratio of treated to control spores is more than one-half. It is proposed therefore to increase the dosage until an appreciable amount of killing is obtained.

Of the 119 ultraviolet mutants so far obtained, 11 are "dwarfs," 18 "unstable," 40 "semilethals," and 50 unclassified; of 99 X-ray-induced mutants, 11 are "dwarfs," 14 "unstable," and 3 "semilethal." Of about 40 ultraviolet-induced mutations subjected to preliminary genetical analysis, 1 is possibly a two-gene change, and the others behave as single-gene mutations. Of 23 X-ray-induced mutations, 12 may be single-gene mutants, whereas 11 are definitely not single-gene mutants. Of these 11, 7 show the type of ascospore sterility associated with chromosomal alteration. In

addition, 10 other X-ray-induced mutations gave empty perithecia when crossed with normal.

In the case of the ultraviolet experiments, in which wave lengths with an appreciable effect in inducing mutations are used, the mutation rate increases with increased energy up to a certain point, and then decreases. The X-ray results show a steady increase in mutation rate with dosage, up to the highest dosage given. It is necessary to increase the X-ray dosage until an appreciable amount of killing is obtained, in order to see whether this will be accompanied by a fall in the mutation rate or whether the fall in mutation rate is peculiar to the ultraviolet treatment. The high rate of occurrence of semilethals in the ultraviolet experiments, as contrasted with the X-ray experiments, raises the question whether they are to be correlated with the high death rate in the ultraviolet experiments or whether they are a special effect of the ultraviolet treatment. This question also may be answered by increasing the X-ray dosage.

The suggestion that single-gene mutants are more frequent in the ultraviolet experiments, where they may be almost the only type of mutant, is in accord with expectation.

The unstable or reverting types of mutant raise special problems. Reversion probably results from the overgrowth of "normal" nuclei in a heterokaryon consisting of normal and mutant nuclei. The heterokaryotic condition of the mycelium may be brought about in several ways. It may result from a mixing of nuclei, because a "mutated" and a normal spore are picked up together; or one spore may give rise to two types of nuclei, because only one chromatid of a divided chromosome is affected. Another possibility is that reverse mutation occurs either at the same

or at a different locus. However the heterokaryotic condition is brought about, it results in a unique situation in which natural selection may occur within an organism.

GIANT CHROMOSOMES IN MOSQUITOES

Dr. Sutton has studied giant chromosomes in two species of mosquito, *Culex pipiens* and *Aedes aegypti*, eggs of which were obtained by courtesy of Dr. J. Maier, of the Rockefeller Institute, New York.

The giant chromosomes are found in the salivary glands, mid-gut, and Malpighian tubes of the larvae, and persist to the adult stage in the Malpighian tubes. Fairly satisfactory preparations were obtained by using the Malpighian tubes of fourth-instar larvae, pupae, or newly emerged adults, which had been kept at 10–18° C. for a few days, pretreating with acetic-alcohol for 1 minute, and staining with acetic orcein (1 per cent orcein in 45 per cent acetic acid) for about 1 hour.

The giant chromosomes have the characteristic banded structure of the salivary-gland-type chromosomes studied in other Diptera. Both the species studied have a haploid chromosome number of 3. In *Culex pipiens* the individual chromosomes can be followed along their whole length, but in *Aedes aegypti* their continuity is confused by numerous contact points between different chromosome arms and a tendency for the chromosomes to break at these points.

This investigation gives some reason to believe that a comparison of giant-chromosome maps might be useful as a means of distinguishing between different species and subspecies of mosquitoes. Some observations on the development and a brief description of the characteristic features of the giant chromosomes in the two species have been published elsewhere.

THE THEORY OF CONJUGATED DOUBLE BONDS

The fundamental properties of a large number of compounds important in organic and biologic chemistry are known to be determined by the presence of chains of conjugated double bonds. The nature of the phenomenon of conjugation has been understood theoretically for a number of years, but attempts to develop a detailed theory of the systems of conjugated bonds have not yet progressed very far. A part-time project was undertaken by Dr. Fano, directed toward an understanding of the correlation between the absorption spectrum—that is, the “effective color”—and the length of an aliphatic chain of conjugated bonds. It was found, in the first place, that no essential discrepancy exists between the present experi-

mental and theoretical knowledge on this subject. Further knowledge was gathered on other theoretical questions, among which are the following: (a) the effect of electronic exchange on the absorption spectrum, especially for very long chains; (b) the difference in properties between chains involving different terminal groups; (c) the correlation between the absorption spectrum and the shape of the chain (this correlation allows us to reach certain conclusions on the shape of the chain, a subject about which very little is known yet, either theoretically or experimentally); (d) an approach to the theoretical determination of the most stable shape of the chain. This project was, however, discontinued because it was expanding beyond expectation under circumstances which seemed to be unsuitable to its further development.

MOUSE GENETICS

E. C. MACDOWELL, J. S. POTTER, V. BRYSON, M. J. TAYLOR,
E. N. WARD, AND T. LAANES

SPONTANEOUS LEUKEMIA: FOSTER-NURSING EXPERIMENT

In certain mice the incidence of spontaneous leukemia can be modified by a maternal influence transmitted in the process of nursing and differing according to the strain of the nurse (Year Book No. 40). The surprising thing about this result is that the degree of the influence is not necessarily correlated with the frequency of leukemia in the nurse's strain. That nurses from two low-leukemia strains might differ in their influence was not even conceived when the above experiment was planned, and nurses from the two strains were used for purely practical reasons.

Although attention has been directed primarily to the role of genetic constitution, this result carries such interesting implications that its full confirmation and

interpretation appear to be an obligation. After long deliberation on the minimum requirements for critical evidence, an experiment to test this nursing influence directly has been undertaken; and, with the weaning of all the experimental animals, the initial phase has been completed. The establishment of this long-time experiment is reported in some detail in the interest of cooperation and of avoiding wasteful duplication.

Each litter from reciprocal matings between strains C58 and StoLi was distributed at birth as evenly as possible to foster nurses from each of the three strains C58, StoLi, and Bagg albino (Balb), making six experimental classes. The first milk of the nurses had been taken by other young, but the first milk obtained by the experimental animals came from

their foster nurses. To obtain 416 entirely unnursed young and raise 403 of them successfully with a variety of foster nurses is, in itself, an accomplishment. In order to maintain conditions as normal as possible, all treatment of mothers' nipples and all mechanical devices were avoided; each young was removed from the nest by hand soon after its birth, and held in cotton wool until the last of the litter was born and the foster nurses were ready. To do this, four observers shared a continuous night-and-day watch of the females approaching term and recorded a series of direct observations on parturition behavior and birth times of individual mice. This appears to be the first time that any comparable series of observations has been made on the mouse. Many questions are raised, and a new approach to an understanding of the processes of parturition is suggested.

A contrast appeared in the parturition behavior of the mothers from the two strains. Those from strain C58 concentrated their attention on the job and carried it through with directness and assurance. The fetal membranes were usually broken by the mother in assisting the delivery; after a young was well cleaned, the placenta, which often did not appear till later, would be rapidly and completely eaten. StoLi mothers were generally highly nervous; their attention wandered and the various operations were performed vaguely, in fits and starts. The young might not be completely cleaned and the placenta was seldom more than nibbled about the edges. The young and placenta frequently appeared together, with all membranes intact; the placenta might be somewhat eaten, but the young left unrecognized within the membranes. In such cases, however, the observer would remove the membranes and save the young. The rapidity of asphyxiation in unbroken membranes suggests that the dehiscence

of each placenta must precede the delivery of each young by a very short time, and that the separation of the placenta is the immediate determinant of an individual birth; it follows that the order of dehiscence is regularly from behind, forward. The birth of an entire litter commonly requires a whole hour and occasionally much longer.

A further strain difference appeared in the distribution of births with relation to the time of day. The 28 litters from StoLi mothers were scattered fairly evenly throughout the twenty-four hours, with a slight accumulation at 4 A.M. accounting for 4 more births between midnight and noon than between noon and midnight. Of the 29 litters from C58 mothers, 28 were born in daylight. Starting with one at 4 A.M., the frequencies tended to increase till 5 P.M.; none was born between 6 P.M. and 4 A.M.

At 28 days each hybrid mouse was weaned, marked, weighed, and assigned to a permanent box together with a mouse from each of the other five experimental classes, as far as this was possible with sexes separate. The proportion of males from C58 mothers was less than from StoLi mothers (42 per cent and 54 per cent). The weaning weights provide a measure of the relative success of the different strains of nurses, since the distribution of newborn animals was purely random and since each nurse in a set of three always raised the same number of young (5 in almost all cases). Inequalities within sets of three were removed by adding newborn Bagb albinos where necessary.

The frequency distributions of weights of the 28-day young show unquestionable differences according to the strain of the nurse. The modes for the three distributions lie in ascending 1-gram classes in the order C58, StoLi, Balb; but the means for C58 and StoLi nurses are about 0.5 g.

apart, whereas the means for StoLi and Balb nurses are 2 g. apart. How long these effects of the different kinds of nurses on weight will persist, and whether they have any connection with the nursing influence on leukemia, will appear later.

SCREW-TAIL MUTATION

Continued study of mice showing the screw-tail mutation, first reported last year, has added numerous effects to the already extensive list and correspondingly enlarged the range of problems presented. The new problems bear particularly on the determination of skeletal pattern. Each terminal effect offers a clue to the developmental mechanics of a given part. After these specific mechanisms are recognized, determination of the interrelation of their antecedent stages becomes the goal. That they all depend upon one gene indicates some ultimate interrelation. Whether one gene may have more than one action is frequently discussed. It would seem more helpful to ask, At what stage and why do the chains of events leading from one gene to the diverse terminal effects become separated? In such a search the basic problem of differentiation in development becomes identified with the problem of gene action.

Many mutations, when not lethal in early stages, confuse the processes of development so violently that they contribute little toward the analysis of normal developmental processes. The outstanding importance of the screw-tail mutation is due to the moderation of its effects, which therefore become relatable to normal.

The original evidence that this mutation is due to one gene has been amply confirmed by more than doubling the number of mice from segregating pairs (total, 2998 mice); by raising the number of tested normal sibs of screw-tails to

76 (51 heterozygous, 25 homozygous); and by the reappearance of the mutation, intact, from outcrosses into two different strains (one of these crosses was made by Dr. L. C. Dunn at Columbia University). A deficiency of screw-tails, originally reported for males only, now appears to be evenly divided between males and females. This is ascribed to prenatal loss, which becomes selective for screw-tails only in the presence of unfavorable conditions as indicated by increased prenatal mortality of normals. As reported at one time from this laboratory, prenatal mortality of normal mice is lowest in first litters and increases with successive litters. In first litters the expected proportion of screw-tails is found; in later litters the total number decreases and the proportion of screw-tails is reduced until it finally approaches zero. Thus the numerical deficiency of screw-tails shown by the totals depends on the number of litters included from each mother and has little significance. This result does not indicate whether the increasingly unfavorable conditions are due to the number of preceding pregnancies or to the age of the mother, but it does establish a type of variable selective elimination that may very possibly help to explain other cases.

The following newly discovered effects have been studied in an extensive series of alizarin-stained skeletons ranging from 2 days before birth to more than a year afterward:

1. The pelvis is shifted about one vertebra nearer the tail, separating the ilium from the initially first sacral vertebra, which develops as a lumbar vertebra, free from the remaining three sacral vertebrae. The consistency of this effect will permit an embryological study that will bear directly on the interpretation of the variations often found in the number of human lumbar vertebrae.

2. The centra of scattered thoracic and lumbar vertebrae are malformed. They arise from paired, instead of single, bone centers, and as maturity approaches cause sharp spinal flexures, bending outward.

3. The lower jaw is grossly malformed. Even before birth the pattern of the jaw shows a deviation from normal. The distortion becomes progressively more extreme through a large part of life, in connection with the abnormal growth of the teeth.

4. The lower incisor teeth do not grow back into the ramus of the jaw; both upper and lower incisors show defective enamel formation and curve in too sharply. These conditions lead to abnormal wearing of the cutting ends in all cases, and frequently to extreme malocclusion. In old age, forward growth of the incisor through the jaw may become blocked so that the basal end is forced backward through the solid bone, sometimes penetrating its surface. The specific relation between various physiological states and variations in the structure of rat incisors demonstrated by Schour gives the histological study of these teeth great importance.

5. Roots of molar teeth are always feebly developed, and there is only one socket for each tooth instead of a separate socket for each of the three roots. Some of the molars are frequently absent or mis-oriented. The failure of root development, even when a single molar lying on its side is the sole occupant of the tooth cup, indicates a defect within the tooth rather than an abnormality in the growth of the surrounding bone.

6. The top of the skull shows the sagittal sinus permanently uncovered by bone and the coronal suture arching sharply backward with numerous small sutural bones. The modification of these membrane bones, as well as of the jaw, shows that the action of the gene is not limited to carti-

lage bone, or rather cartilage, for no evidence has appeared to indicate that the actual process of ossification is in any way abnormal.

7. From the first deposition of bone the sternum is always a single, unsegmented bone, shorter and broader than normal; the first and fourth to seventh ribs are always attached, but the ends of the second ribs are frequently free, as are the ends of the third ribs occasionally.

Since more questions have been raised than answered by the study of the above effects, further comment will be reserved on all but the sternum, which warrants a fuller account.

The absence of all traces of segmentation not only makes the screw-tail sternum an unparalleled mammalian structure, but also provides a clue to the cause of the normal pattern. Hanson has interpreted the presence of *sternebrae* "as arising from a process of segmentation in response to the demand for as great a measure of elasticity on the ventral side of the animal as is allowed by the more or less flexible vertebral column of the dorsal side. Sutures arising in this manner, as a result of strain, will naturally appear at the weakest parts along the sternum. At the points of attachment of the ribs the sternum is often deeply notched, weakening this region, and here, as expected, occur the lines of division of the sternum into segments or *sternebrae*." The following provides an interpretation more closely related to the actual developmental processes:

In the embryonic sternum of the mouse a persisting growth center is established at the end of each rib. Although the rib end is histologically homogeneous, a gradual differentiation from the most immature to fully differentiated cartilage cells can be followed, passing from the rib end in any direction into the sternum. In screw-

tails, the opposite rib ends are so far apart that the zones of immature cells on the right do not meet those on the left and the oldest cartilage forms a continuous band along the mid-line. Since bone can be deposited only after cartilage is fully mature, the first bone in a screw-tail sternum therefore forms a continuous longitudinal streak. In normal mice, the opposite rib ends are so close together that the zones of immature cells on the right lie in contact with those on the left, breaking up the mature cartilage cells into a series of separate masses. Thus the bone centers form a series of intercostal bands at right angles to the main axis. The fusion of the right and left growth zones leads to the formation of pairs of transverse epiphyseal growth centers, which account for the elongation of the bone centers, with slight increase in width. In screw-tails, on the other hand, the opposite growth zones cannot unite. Each remains practically in contact with the neighboring zones on the same side, so that at birth the sides of the sternum are bordered by cartilage, whose continued growth primarily increases sternal width.

The dependence of growth centers in the sternum upon the rib ends is admirably demonstrated by the variable failure of second and third screw-tail ribs to become attached. Without exception, there

is never a growth center when the rib fails to reach the sternum, and there is always one when the rib is attached. Wherever there is no growth center, ossification quickly extends to the margin of the sternum, which is always narrower at these points.

A further confirmation of this interpretation has been found in numerous non-screw mice, in which the distance of the rib ends from the mid-line is normal but the two members of a pair are not opposite. This may involve a single pair of ribs or several, and the dislocation may be slight or very marked. Correspondingly, either the growth zones meet at an angle, or they do not meet at all and each remains an independent lateral center exactly as in screw-tails. In every case the bone pattern follows the distribution of fully matured cartilage, from sternebrae with crooked ends, to half-size sternebrae staggered in position on the two sides, and, finally, to a continuous wall of troy pattern with segmentation eliminated.

The longitudinal shift in the positions of rib ends leading to a staggered sternum, and the transverse shift leading to the broad screw-tail sternum, are clearly due to very different causes; but the materials of the sternum in the two cases appear to be intrinsically alike, and equally under the control of the ribs.

ENDOCRINE STUDIES

O. RIDDLE, W. F. HOLLANDER, R. A. MILLER, E. L. LAHR, G. C. SMITH,
AND H. N. MARVIN

The endocrine organs perform a singular type of "team work" concerned with physical and mental development, and at all life stages they share largely in the regulation of reproduction, growth, bodily maintenance, and behavior. Discovery of the extent to which certain hormones of the pituitary gland share in this "team

work" continues as a central aim in most of the studies described here.

HORMONAL BASIS OF MATERNAL BEHAVIOR IN RATS

The results of nearly six years of study of this subject by Riddle, Lahr, and Bates have now been analyzed and published.

More than 2900 tests were made with 19 different hormones or hormonal preparations, to determine the role of hormones in the exhibition of unlearned maternal behavior in rats. The more important facts relating to this prolonged study of an "instinct" are summarized here.

Intact albino rats, aged 60 to 70 days, were tested especially for retrieving (that is, carrying young rats, mice, or squabs to a nest) and cuddling responses daily for 10 days. By this means about 22 per cent of "normal reactors" were separated from the nonreactor rats. Thereafter these non-reactors were subjected to hormonal injection for 10 days, with daily records of behavior extending over a further 10-day period. All hormones were tested on a few or many males and females and on castrates of both sexes.

In responding female rats whose mammarys had been developed with estrone during 20 days, the validity of the criteria of response (that is, retrieving and cuddling) was attested by the ability of these rats actually to feed and rear the adopted young.

The maternal drive or instinct was initiated in large or in significant numbers of normal and castrate male and female rats during injection (or pellet implantation) with various hormones: prolactin, progesterone, desoxycorticosterone, intermedin, luteinizing hormone, phenol, and thyroxine; testosterone failed only in normal males. The instinct was not activated by injection with follicle-stimulating hormone, "growth" hormone, adrenotrophin, Prolan, pregnant mare serum, parathyroid extract, or a special extract of thyroid tissue.

Most, but possibly not all, of the effective substances rather clearly exerted an anti-gonad action on the intact rats; the term anti-gonad seems inapplicable to luteinizing hormone, although it too had a tendency to arrest estrous cycles. Castra-

tion alone slightly increased the proportion of "normal reactors," and also increased the effectiveness of all substances capable of exciting the maternal response.

Intact males were as likely as intact females to be "normal reactors," but non-reacting (control) males were more resistant than (the slightly smaller) females to the maternalizing action of all the effective hormones.

Pregnant mare serum, gonadotrophin plus thyrotrophin, and estrone all had much or appreciable ability to terminate well established maternal behavior. These substances do not exert this action in rats deprived of their hypophyses, but they are effective in thyroidless rats.

Removal of the pituitary gland precipitates maternal behavior in approximately 50 per cent of otherwise intact female rats, but not if a decrease of the ovarian function is prevented by injections of pregnant mare serum. Nonreactors following hypophysectomy can, in most cases, be made maternal with either prolactin or progesterone.

In male rats, thyroidectomy alone excites maternal behavior in about 25 per cent of such tests. Male rats not made maternal by this operation seem thereafter more resistant than normal rats to the positive action of prolactin, progesterone, and luteinizing hormone.

The degree of purity or of contamination of the various pituitary preparations used was ascertained. Progressively larger doses of prolactin—6, 18, and 30 units—progressively increased the percentage of rats of all sex types made maternal by treatment.

Recurrent maternal behavior in reproducing rats (the rats tested were not in reproduction) probably does not depend on the several hormones here found to be directly or very indirectly active, but on that one of the group which (*a*) is released in increased amount at the right

time, (*b*) exerts an anti-gonad action, and (*c*) then directly or indirectly increases the excitability of the sensorimotor mechanism specifically involved in this instinctive behavior. Though present information is inadequate, the hormone that apparently best fits these requirements is prolactin.

Genetic relationships and differences between mating drive and maternal drive become clearer in the light of results obtained in the present study and in our previous study on broodiness in fowl. The mating drive, or perhaps merely an unexpressed basis for that drive, is apparently a necessary precursor of the maternal drive. It thus appears that the maternal drive or instinct is remotely conditioned by the pituitary hormones (gonadotrophins) which govern the building of egg, sperm, and sex accessories, and is probably precipitated and regulated by another pituitary hormone (prolactin) which is related broadly to the feeding and care of young.

PITUITARY HORMONE ACTION IN CARBOHYDRATE AND FAT METABOLISM

Last year's report noted that those extracts from anterior pituitary tissue which have marked "diabetogenic" actions are mixtures of hormones. The extent to which posterior-lobe hormones (and intermedin) contribute to the effectiveness of those mixtures was then almost wholly unknown. This topic has been investigated during the present year by Riddle and Marvin, but the results can be described more conveniently in connection with a summary statement on the entire subject which is planned for next year.

A valuable aid to study of the hormones contained in effective extracts was rendered by Drs. E. M. K. Geiling and G. Chen, of the Department of Pharmacology, University of Chicago. Utilizing their

newly developed methods for the assay of intermedin (melanophore hormone), they have examined our standard-type pituitary preparations and determined that their content of melanophore units is as follows: whole anterior pituitary extract (no. 650), 1760 units; gonadotrophin plus thyrotrophin (no. 630), 2000 units; prolactin (no. 657), 94 units; prolactin (no. 861), 100 units; a "mother" fraction (no. 804) from which ammonium sulfate fractionation is done (see last year's report), 340 units; whole posterior pituitary (alkaline) extract (no. 779), 2940 units; whole extract of beef muscle (no. 681m), 0 units. This information makes it possible to estimate or to exclude the effects of intermedin on the sugar, glycogen, fat, and ketone values obtained following the use of our standard preparations.

Gross differences in response of the liver to first and later daily dosage with insulin and prolactin. Studies on this topic were largely completed by Riddle and Opdyke prior to the present year, but the results were reported only in part last year. Pigeons survive huge doses of insulin, and it is known that a course of 4 to 7 daily injections of prolactin doubles the weight of their livers. Young pigeons were given from 1 to 5 daily injections of insulin or prolactin, and differences between the response to a first and to subsequent injections were measured in the case of liver glycogen and fat, ketonemia and glycemia. All values were obtained at the end of a 24-hour fast. A first treatment with insulin (70 units per kilo of body weight) was found to increase liver fat by about 160 per cent, but under further dosage the fat falls to or below the normal values. First, but not later, insulin injections produce ketonemia (at 10 hours after injection). Twelve hours after a first injection the blood sugar is decreased by 25 per cent,

but 12 hours after a second daily injection it is increased by 50 per cent in both normal and hypophysectomized birds. Twenty-four hours after a first injection of prolactin the percentage of liver glycogen is increased, but third and later injections neither maintain nor produce this increase; in these tests, and during at least 6 days, total liver fat is increased essentially parallel with increase of hepatic tissue.

Though the nutritive state of these animals is affected by temporary and prolonged dosage with either insulin or prolactin, these results mainly reflect the ability of the first dose of these hormones to set a new level of functioning in one or another regulatory organ (adrenal, pancreas, pituitary). These studies, therefore, contribute to an understanding of the normal mechanism concerned in the regulation of carbohydrate and fat metabolism.

Effects of anterior pituitary preparations and insulin on islet cells of the pigeon pancreas. There is uncertainty concerning the number and the cellular sources of hormones secreted by the pancreas, and also uncertainty concerning functional interrelations between pituitary and pancreatic hormones. Other current studies, particularly those on carbohydrate and fat metabolism, have supplied an abundance of variously treated pancreatic tissues which are suitable for a clarification of some of the above-mentioned problems. This material has been utilized during the past two years by Dr. Miller, with the results stated below.

Three types of islet cell are identifiable in the pigeon pancreas. In young Carneau pigeons fasted 10 days, and in pigeons whose pituitary glands have been removed, the beta cells seem inactive or degenerating; only slight changes in alpha and delta cells occur. Force-feeding of hypophysectomized pigeons maintains a normal appearance in the three types of cell. Prolactin, overfeeding, partial pancreatectomy,

and some preparations of corticotrophin all stimulate beta cells; gonadotrophin and thyrotrophin have no effect. Large doses of insulin induce a marked atrophy of beta cells.

Four series of pituitary extracts obtained by fractional precipitation with ammonium sulfate (whose effects on glycemia, ketonemia, and liver fat were fully described in last year's report) were tested in normal and hypophysectomized pigeons and found to induce degenerative changes in beta cells. Stimulation of delta cells was observed with certain fractions from 10 hours after a single injection to 24 hours after the last of 7 daily injections. Substances stimulating delta cells are most concentrated in material precipitated at one-third saturation (fractions *B* and *C*) and tend to be insoluble on dialysis. There is an association between the delta-cell-stimulating action of these fractions and their ability to increase liver fat. Limited delta-cell stimulation occurs in pigeons treated with prolactin and with insulin. The actions of ammonium sulfate fractions on delta cells are not directly associated with any particular one of the hormones known to be present in these impure preparations.

The granules of alpha cells are markedly depleted by insulin and less markedly by some ammonium sulfate fractions and by corticotrophins.

The cytology of the pigeon adrenal cortex in experimentally induced atrophy and hyperactivity. The activity of the adrenal cortex is at least partly controlled by the pituitary gland, and one or more hormones produced by the cortex are known to play a part in carbohydrate metabolism. These facts led Miller and Riddle to a careful study of the cellular changes that accompany hormone production in cells of the adrenal cortex. The appearance of the Golgi apparatus, mitochondria, lipid,

cholesterol, and water-insoluble ketones in adrenal cortical cells of young (1.9 to 2.4 months old) normal Carneau pigeons was compared with the cytological picture in experimentally induced atrophy and hyperactivity. The conclusions now drawn from this study complete and notably supplement the related studies described in earlier reports.

Mitochondria seem to be involved in the formation of cortical hormone(s) which, together with a possible precursor (cholesterol), is present in the lipid droplets. The rate of formation of lipid normally exceeds the demands of the organism, and storage results. The Golgi apparatus may transform lipid into the final product. In stimulated adrenals a marked proliferation of mitochondria maintains the rapid formation and excretion of lipid; cholesterol, lipid, and water-insoluble ketones are diminished. Following hypophysectomy cortical activity is limited to a few peripheral cells, and in a few adrenals these peripheral cells give little or no indication of activity. Injections of cortical hormone into unoperated pigeons cause atrophy of the cortex; similar injections into hypophysectomized pigeons further decrease the weight of the gland and suppress the activity of cells in the peripheral zone. In hypophysectomized pigeons, formaldehyde and several nonpituitary hormones produce cytological changes in the cortex which are similar to those resulting from corticotrophin. Adrenal cells of normal nestlings and adult pigeons show greater activity than do those of young preadolescent pigeons.

Alleged thymus mediation of pituitary function. A series of papers published in 1940 by Bomskov and co-workers in Freiburg reported the preparation and the extensive investigation of an ether-soluble extract of the thymus. Such an extract was said to be "diabetogenic" in rats, guinea

pigs, and pigeons, in that it showed marked glycogenolytic and hyperglycemic actions. Those investigators further claimed that a diabetogenic-thymotrophic fraction obtained by them from the pituitary gland is identical with "growth" hormone, and that physiologic effects of the latter pituitary substance are thus also mediated by the thymus hormone. The strong claims of these workers to a resolution of problems in which this laboratory has long been interested led Wells, Riddle, and Marvin to repeat the Freiburg studies. With none of three preparations of an ether-soluble extract of calf thymus was it possible to confirm the reports of the Freiburg group. Neither glycogenolytic, glycemic, nor ketogenic activity was observed in rather extensive tests on rats and pigeons. No significant leucocytosis was obtained in rats. Short-term tests showed no appreciable effects on bodily growth in young rats, chicks, or pigeons.

A technique for thyroidectomy in the pigeon and the early effect of thyroid removal on heat production. Investigations frequently require the use of birds completely deprived of their thyroid tissue, and the technique hitherto employed in this operation on pigeons was in some respects unsatisfactory. Marvin and Smith have developed a technique for a two-stage operation that avoids the immobilization of the crop ("crop binding") which is frequent when other methods are used. Elimination of this effect increases the usefulness of the operated birds for the various studies on metabolism that require thyroidless birds. The effect of the operation on the respiratory metabolism is almost immediate. The basal heat production of 8 birds was apparently somewhat depressed at 4 to 5 days after the removal of one thyroid, and in 13 birds the basal metabolism was -20 at 7 to 8 days after complete thyroidectomy; in another group of 7 pi-

geons a value of -27 was obtained at 6 to 46 days after complete thyroidectomy. Almost all birds survive this operation, and the technique permits a rapid and usually a complete removal of the thyroids of pigeons.

ADRENAL CORTICAL HORMONE AND PROLACTIN

The relation of hormones of the adrenal cortex to growth. During the past few years this laboratory has directed some effort to an analysis of the means by which the anterior pituitary gland promotes and regulates growth. In tests made with mammals, other laboratories have essentially failed to find that adrenal cortical hormones—all probably produced under stimulation by pituitary corticotrophin—support or increase body weight in hypophysectomized animals. Using pituitaryless pigeons, Miller and Riddle have obtained positive results with cortical extract, and particularly with desoxycorticosterone acetate; moreover, this effect on body weight has been shown to be additive to the support afforded by minute doses of prolactin. The present experiments represent short-term tests, and they are more directly concerned with prevention of the large loss of body weight that follows removal of the pituitary, but their bearing on the problem of growth is evident. Parts of the data are shown in figure 2.

After removal of the anterior pituitary gland from groups of Carneau pigeons aged 7 weeks, the birds were injected daily for a period of 10 days, then sacrificed, and the weights of various organs obtained. Operated birds given no treatment during this 10-day period show an average loss of 21 per cent of their body weight. Groups of operated pigeons injected with an extract of adrenal cortex lost 13 and 14 per cent of their original

weight. When these birds were injected with desoxycorticosterone acetate at optimal dosage, 2 to 3 mg. daily, this loss of weight was reduced to 6 per cent; doses larger than 3 mg. were toxic. When this substance and testosterone propionate were injected together, the male sex hormone showed no ability to assist growth or to maintain body weight. Groups injected daily with 1 mg. desoxycorticosterone lost 10 per cent, and those injected daily with 1 unit of prolactin lost 8 per cent, of their preoperative weight. When these quantities of the two hormones were injected together, the birds regained all the weight lost as an early or incidental result of the operation (see fig. 2) and at killing were 1 per cent heavier than at the start of the test. Preliminary tests, which are subject to further confirmation, have suggested that the injection of only 0.005 mg. of thyroxine in addition to 1 mg. of desoxycorticosterone and 1 unit of prolactin increases this gain in body weight to 4 per cent. This gain equals the average gain shown by animals that retain their pituitaries and are subjected to no operation during this same 10-day period. These hormones, and mixtures of hormones, also maintained or increased the weights of the intestine and liver, but they had no similar action on thyroids, testes, and adrenals.

The hormones that replace the effect of the pituitary in the maintenance or increase of body weight stimulate appetite and food consumption notably, and they apparently enable pigeons to utilize their food more efficiently. Extract of adrenal cortex and desoxycorticosterone also markedly increase the intake and output of water. Determinations of the water content of breast muscles and livers of treated and control birds show that the support of body weight by these hormones is not accomplished by, and is not a consequence of, the hydration of these tissues.

Smaller numbers of tests of the action of cortical hormone and prolactin in adrenalectomized pigeons support the conclusion already presented. Uninjected adrenalectomized pigeons lost 12 per cent of their preoperative weight in 10 days. Daily dosage with 50 units of prolactin caused a

Local crop-sac or micro method for assay of prolactin. Two years ago it was noted that several nonpituitary substances, when injected intracutaneously over the crop, stimulate cell division in the lining of the pigeon's crop sac. Those observations indicated that certain precautions

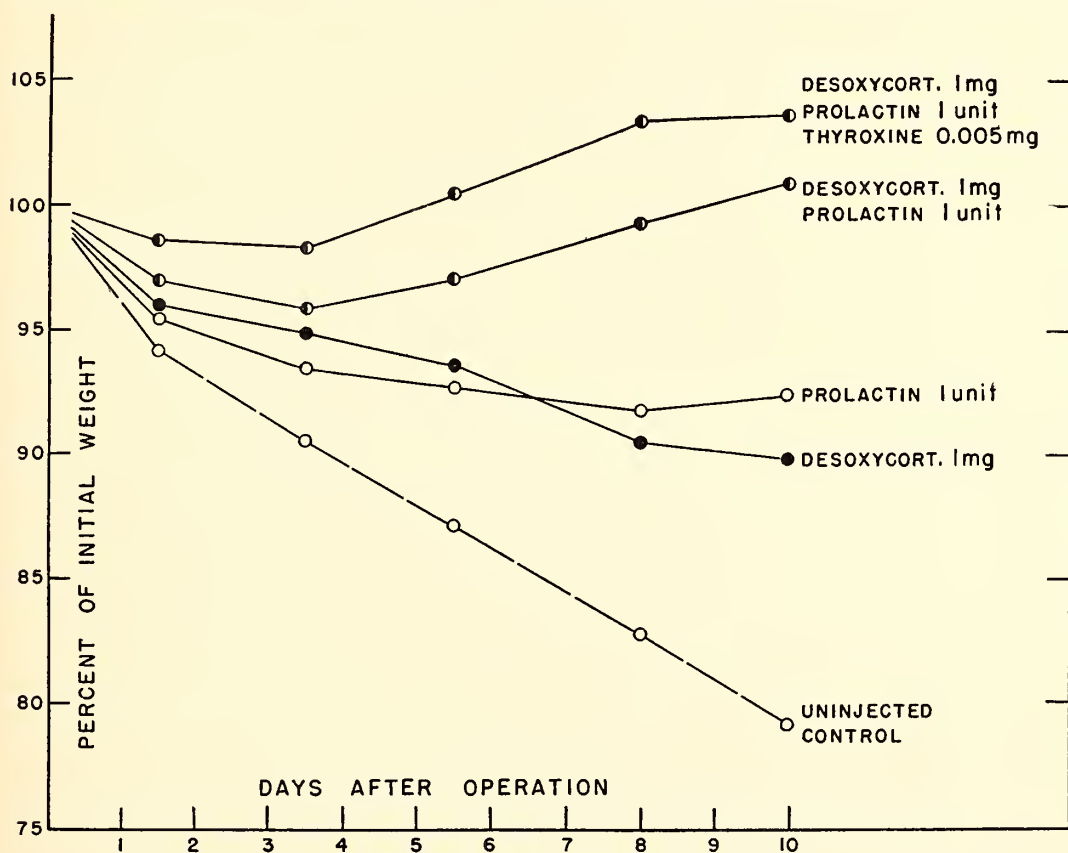


FIG. 2. Graph showing support of body weight in groups of pigeons (10 to 38) by daily injections of desoxycorticosterone acetate with and without the addition of 1 unit of prolactin. The data are for the 10-day period immediately following the removal of the anterior pituitary gland of Carneau pigeons aged 7 weeks.

significant temporary increase in weight, but at the end of 10 days the animals (some near death from lack of life-maintaining cortical hormone) had lost about 8 per cent of their preoperative weight. Birds of one group injected daily with extract of adrenal cortex together with 50 units of prolactin increased their body weight by 9 per cent in 5 days.

must be taken in the use of this method for the micro-assay of prolactin. At that time, however, it was not possible to account for the disturbing fact that two seemingly valid criteria of crop-sac stimulation were in frequent disagreement. Thus, at 24 or 48 hours after an injection many of the crop sacs examined by transmitted light seemed thickened and rugose

(positive response), though actual counts of dividing cells (after colchicine) showed no increase in the rate of cell division. During the present year Lahr and Riddle have clarified this difficulty by showing that visible thickening and rugosity may result (and persist for 48 hours) from increased cell divisions strictly limited to short periods (2 to 7 hours) following the injection. An entirely normal rate of cell division in an epithelium that was definitely thickened as a result of an earlier treatment involves, therefore, no real contradiction. It was shown, further, that leukotaxine (1.0 mg.) is one of the substances that temporarily (4 and 7 hours) stimulate mitoses and also tend to show visible stimulation (positive response) at 24 or 48 hours after the last previous injection. This demonstration that a "wound substance" shares in this response, and that its action is immediate and of short duration, has special significance; it supports the view that the entire list of nonspecific substances may exert their action on the crop epithelium as a secondary result of their excitation of "wound substance" in or near the lining of the crop. In contrast, prolactin is effective when injected at sites far removed from the crop sac; its specific ability to cause proliferation of crop epithelium wholly independent of "wound substance" therefore seems unquestionable.

BREEDING OPERATIONS AND STUDY OF ENDEMIC GOITER IN PIGEONS

In February 1942, Dr. Hollander became associated with this group, more especially to assist in the genetic analysis of breeding operations conducted by Riddle on doves and pigeons during more than twenty years, and in the preparation of this material for publication. In addition, certain genetic and physiological tests on some

segments of this large bird colony are continuing with his aid or supervision.

Adequate analysis now clearly shows that the "scraggly" pigeon character, which has been extant in the colony since its inception, is a simple recessive trait. The ratios obtained in summaries of the four possible types of mating show a moderate deficiency in the scraggly classes, but this is interpreted as evidence of a higher mortality of scragglies than of normals during the early period (to 10 to 14 days after hatching) when scragglies cannot easily be distinguished from normals. Plumage and skin defects, and an abnormally high rate of heat production, definitely distinguish the scragglies from normal birds.

Outcrosses of females of our hermaphrodite-producing strain of pigeons to males of normal stocks have produced a high percentage of sons having rudimentary left oviducts, but no ovotestes have appeared. On the other hand, hermaphroditic or partially hermaphroditic males (those merely with left oviducts) outcrossed to females of normal stocks have given thus far only normal offspring.

The apparent relation of endemic goiter in pigeons to embryonic weakness has led to an investigation of this subject. Thyroid enlargement, up to 250 times normal size, has been observed occasionally in our pigeons over a period of many years. The study is still in progress, but it is clear that the goitrous tendency is most marked in old birds and among pigeons of the large breeds; it is rare in the ringdoves. It has been established that occurrence of enlarged thyroids in reproducing female pigeons is highly correlated with poor hatchability, late hatching, and the production of weak offspring. Reference to the fact that eggs from goitrous female pigeons require 2 to 3 extra days of incubation was contained in the report for 1929-1930

(Year Book No. 29). It is now found that the offspring of goitrous mothers also usually have large thyroids at hatching.

Preliminary tests for effects of supplements of potassium iodide in the mother's diet indicate that her enlarged thyroids regress toward normal size within a few weeks, and that there is coincident improvement in the hatchability of her eggs and the vigor of her offspring. The effect of this treatment on the heat production

of these adult birds is not yet adequately determined, but Smith has shown that short-term administration of larger doses of the iodide to groups of young pigeons increases their rate of heat production by 5 to 19 per cent. Extremely goitrous pigeons have shown clear evidence of deficiency of thyroid hormone; their ability to regenerate feathers spontaneously from plucked areas is greatly decreased and their basal heat production is diminished.

ANTHROPOLOGY AND HUMAN GENETICS

MORRIS STEGGERDA AND CATHERINE SHAFFER

ANTHROPOMETRY

Child development. It is known that some human populations are taller and heavier today than they were in years past. For example, students from some colleges are taller and weigh more on the average than did their parents when they attended school. United States soldiers are said to be heavier now than were the soldiers in the First World War, and they, in turn, were heavier than those of the Civil War. This tendency has been reported from various parts of the world and is often accounted for by better living conditions. Meredith, reporting on data from Iowa school children, showed that mean statures and weights for children in 1930-1937 were respectively $\frac{3}{4}$ inch and 3 pounds greater than those from the preceding decade. Similarly, data from the schools of Hagerstown, Maryland showed an increase in weight for children measured in 1940 as compared with those measured in 1933.

When the present study on the growth of children of different races began, in 1931, it concerned the growth of individuals and did not deal with mass statistics. In 1941, however, in view of the previously mentioned trends in growth, a large

number of Dutch white and Navajo children were measured for stature and weight. These data were averaged for each age, sex, and race. By combining all the Dutch white children measured in 1931 to 1934 and the Navajo children measured in 1932 to 1934, a sufficient number was obtained for comparison with the 1941 groups. The results obtained are summarized briefly in table 1 and in figure 3.

It will be noticed from table 1 that, for every age, the 1941 children are taller than those of 1931-1934. Most often the differences are not statistically significant. The trend, however, is definite. The differences in the 11- and 16-year groups are more than three times the probable error of the difference, and may be considered statistically significant. A weighted average of the differences shows that the children of 1941 are 13.63 mm. taller than those of the 1931-1934 group. For weight the same condition exists in that, for every age, the 1941 children are heavier. The weighted average of differences here is exactly 5 pounds. In nine of the twelve age-group categories the differences are significant, being more than three times the probable error.

The data for the Dutch white females are practically identical, showing the weighted average of stature to be 12.54 mm. greater for each age in 1941 than in

the results for the males are similar. It will be noticed that the height of the 1941 Navajo children is greater for each age than that of the 1932-1934 children. Simi-

TABLE 1

MEANS AND PROBABLE ERRORS FOR HEIGHT AND WEIGHT OF DUTCH WHITE MALE CHILDREN MEASURED IN HOLLAND, MICHIGAN, 1931 TO 1934, AS COMPARED WITH OTHERS MEASURED IN 1941

AGE	1931-1934			1941		
	No.	Stature (mm.)	Weight (lbs.)	No.	Stature (mm.)	Weight (lbs.)
6...	100	1151.40±3.11	44.80±0.35	88	1162.96±3.65	45.91±0.43
7...	100	1218.20±3.21	50.25±0.43	94	1229.58±3.79	52.87±0.63
8...	100	1267.40±3.82	55.00±0.42	95	1274.64±3.78	57.56±0.55
9...	100	1324.20±3.87	62.50±0.54	99	1335.46±3.84	63.92±0.57
10...	100	1375.00±4.37	67.10±0.70	107	1385.14±3.61	70.35±0.77
11...	100	1412.00±3.80	73.05±0.71	105	1431.90±3.95	76.88±0.81
12...	100	1481.20±4.52	84.60±1.19	104	1483.26±4.67	86.16±1.01
13...	100	1528.00±4.86	88.40±0.97	110	1534.36±4.75	94.23±1.09
14...	100	1601.40±5.70	103.10±1.22	57	1619.48±7.97	111.63±1.75
15...	100	1665.00±6.05	111.85±1.43	79	1677.34±7.00	122.63±1.63
16...	68	1690.88±7.10	122.50±1.69	97	1731.86±5.47	136.16±1.49
17...	37	1733.78±6.68	130.34±1.70	90	1754.22±5.08	139.11±1.52

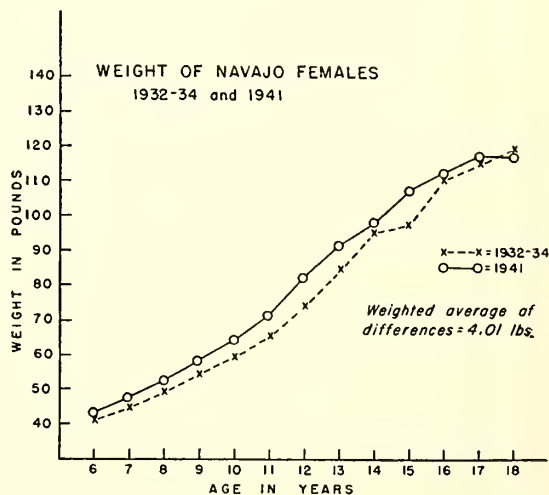
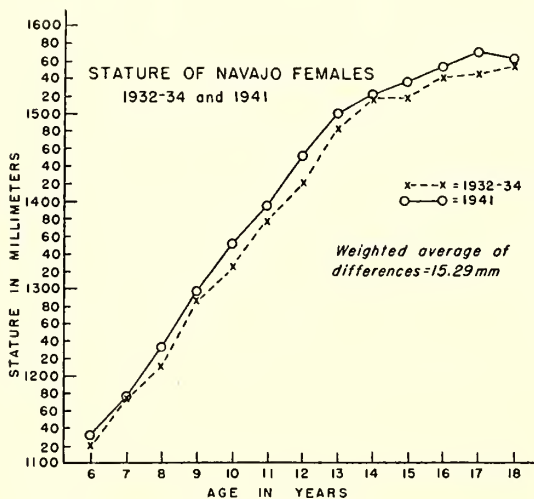


FIG. 3. Height and weight of Navajo female children measured in New Mexico and Arizona in 1932 to 1934, as compared with others measured in 1941.

1933, and that of body weight 4.57 pounds greater.

For the Navajo children, the data are shown in the form of graphs (fig. 3). For these we show only the females, although

larly, the graphs for weight indicate heavier children in 1941 than in 1932-1934. The weighted averages of differences for stature indicate an increase of 15.29 mm. and, for weight, 4.01 pounds. Figures for

male Navajos were 12.07 mm. and 4.67 pounds, respectively.

The unique feature of these data is that the children were all measured by one person using a similar technique. It cannot be said that Dr. Steggerda's technique varied in this decade, for properly balanced scales were used and the same deductions were made for the minimum clothes worn during the measuring. As for the technique for taking stature, he vouches for the similarity of his technique for these two periods.

Believing that still more data would prove helpful, Dr. Steggerda obtained from the Department of Physical Education at Tuskegee Institute, Alabama, the heights and weights of Negro women taken by the teachers during the past decade. The data for 1934 were compared with those for 1941, and the results obtained indicated the same trend as that found for the Dutch and Navajos. The Negro data are not arranged according to age, since the age limits were approximately the same (17 to 23), but rather one mean was made for stature and another for weight for the two periods. The results are summarized as follows: Stature, 1934, 1609.20 ± 2.53 mm.; 1941, 1625.38 ± 2.24 mm. Weight, 1934, 118.47 ± 0.73 pounds; 1941, 121.99 ± 0.69 pounds.

No positive data are available to explain these increases in height and weight during this very short period of time. We are aware of the general increase in height and weight of many human populations. We know that the depression did affect the food intake of the Dutch whites in Holland, Michigan. We know, also, that the Navajo Indians enjoy better living conditions and more healthful surroundings now than they did 10 years ago. We know, further, that the entire population consumes more vitamins and is more conscious of them today than 10 years ago.

But which factors determine the increase has not been ascertained. The present purpose is merely to add these data to the literature with the hope of a future explanation.

Comparative measurements of Negro and white men. In 1938 the physical proportions of 100 Negro women from Tuskegee Institute, Alabama were described and compared with a series of white girls from Smith College who were also measured by Dr. Steggerda. During the present year a similar set of data involving 100 Negro men from Tuskegee Institute has been analyzed and compared with data on white college men supplied by Professor H. H. Plough from Amherst College.

The average stature of the Tuskegee men was 1749 mm., or 30 mm. greater than that of the large Negro army series of Davenport and Love, and 44 mm. greater than that of a group of unselected Negro males supplied by Herskovits. The Tuskegee Negroes were 26 mm. or approximately 1 inch shorter than Amherst College men, although their weight was the same, namely 70.06 kg. In sitting height the Tuskegee students averaged 33 mm. less than the Amherst students, a fact which indicates the relatively short trunks and long legs of the Negro boys. This is shown also in the relative sitting height, which for Negroes is 50.9 per cent as compared with 52.1 per cent for Amherst whites; the average trunk height of the white students, therefore, is relatively greater than that of Tuskegee Negro students. This finding is not at all new, but is included as an additional record.

In biacromial breadth, i.e., width of shoulders, the Tuskegee Negroes averaged 410 mm., or more than the Amherst students, who averaged 402.5 mm.

In span or length of the outstretched arms, the Tuskegee men averaged 1847

mm., or over 2 inches more than the Amherst men. This difference in arm span is more apparent when relative span is considered, namely, arm stretch divided by stature. This for the Tuskegee Negroes averaged 106.2 per cent and for the Amherst students 101.2 per cent, a difference which is highly significant.

In this study of Negro males, 60 direct and derived measurements were considered.

Anthropometric technique. It has long been recognized that the technique of anthropometry varies greatly among anthropometrists. A problem was devised whereby a number of anthropometrists were to measure the same subject in order to determine the extent of the variations for different dimensions. It was planned also to supply the anthropometrist with only one direction, namely, to measure the subject with the technique familiar to him, selecting the dimensions that he deemed important. In this way the relative importance of each dimension as considered by the leading anthropometrists could be ascertained. The subject and Dr. Steggerda visited the laboratories of the twenty-one anthropometrists who participated in this experiment.

The average number of measurements taken by the twenty-one investigators was 24. One took as few as 16, and another took as many as 45 dimensions. Only 18 were taken by more than one-half of the twenty-one investigators.

These 18 measurements showed both uniformity and differences in technique, as was evidenced by the variability of the distributions. Stature, sitting height, head length, head breadth, and nose breadth showed sufficient uniformity to warrant the conclusion that no great differences in technique were involved.

The rest of the 18 measurements, however, were obviously taken with dissimilar

techniques. Intercristal breadth varied from 272 mm. to 324 mm., a difference of more than 2 inches. Nearly the same difference was found for biacromial breadth. The measurements for hand length varied as much as 20 mm., and measurements of the face also showed wide variations. Especially in the measurements involving the location of the nasion were the results too variable for accuracy.

A number of other inconsistencies of technique became apparent. For example, in locating the landmarks on the shoulders and hips there was no uniformity of pressure exerted and no apparent agreement as to whether the points of measurement should be the bony landmarks or the outside contours. Also, there was little uniformity in the instruments used for body measurements. All agreed, for example, that head height was an important measurement, yet four different instruments were used by the eleven investigators who took this measurement.

The experiment definitely showed a need for clearer directions for taking shoulder width, chest transverse, chest A.P. (anteroposterior), intercrystal breadth, nose length, hand length, and hand breadth.

It was recommended to the Society of Physical Anthropologists that a committee be appointed to make the necessary recommendations for the development of uniformity in the study of anthropometry.

CROSS SECTIONS OF HUMAN HEAD HAIR

In Year Book No. 39, a unique method was described for cross-sectioning a large number of human head hairs at one operation. In last year's report a summary was given showing the effects of race, sex, age, and the region on the shaft where the section was made, upon the size and shape of the hair. During the year more work was done relative to the change in size and shape of head hair with age.

Fifty Maya Indian females and 53 males, ranging from the age of 1 to 69, were selected. Approximately 75 hairs from each individual were sectioned and measured. The hair was cut close to the scalp in the same region of the head, and the sections were all made 20 mm. from the original cut. Both the males and the females were put into 10-year age groups, and the means and standard deviations with their probable errors were calculated for the area and for the index. The results are given in table 2.

males in three age groups, and greater in four.

Work on the hair sections is being continued, with special reference to the manner of hair growth in and from the follicles. Histological sections have been made from both Negro and white scalps. Cross sections of hairs in the dermis seem to indicate the same racial characteristics that they demonstrate in hair outside the scalp. Correlations are being made of such cross sections. Information is also being gathered on the shape of the hair follicles,

TABLE 2

MEANS AND PROBABLE ERRORS FOR AREA AND INDEX OF CROSS SECTIONS OF MAYA HEAD HAIR FROM INDIVIDUALS OF VARIOUS AGE GROUPS

AGE GROUP	AREA ($\mu^2/100$)		INDEX	
	Males	Females	Males	Females
0-9.....	27.09 \pm 0.35	27.48 \pm 0.82	88.49 \pm 0.22	88.93 \pm 0.33
10-19.....	37.82 \pm 0.32	33.57 \pm 0.27	83.61 \pm 0.23	82.63 \pm 0.23
20-29.....	40.62 \pm 0.47	40.57 \pm 0.58	83.47 \pm 0.37	80.94 \pm 0.44
30-39.....	39.67 \pm 0.35	35.15 \pm 0.31	80.61 \pm 0.30	84.29 \pm 0.25
40-49.....	33.17 \pm 0.42	35.98 \pm 0.36	80.62 \pm 0.31	77.71 \pm 0.35
50-59.....	39.75 \pm 0.44	32.32 \pm 0.38	81.50 \pm 0.35	83.82 \pm 0.34
60-69.....	32.46 \pm 1.13	29.63 \pm 0.37	80.06 \pm 0.67	85.46 \pm 0.38

From this table it is apparent that Maya hair is smallest in early childhood and increases rapidly in both males and females to a maximum in the 20-29 age group. Thereafter the area tapers off, except for an extraordinary rise in the male 50-59 age group. In the majority of age groups, the females had smaller hair. On the other hand, the index drops considerably, indicating a more elliptical cross section in progressing from the average age of 5 to that of 15. In the males this diminution continues to the average age of 35 and then remains fairly constant thereafter. The female trend is rather irregular, with peaks in the groups 30-39, 50-59, and 60-69; the index is less than that of the

with the aim of correlating this with the final hair shape.

TEETH

Differences and similarities in the teeth of four racial groups have been reported in previous Year Books. Differences have been demonstrated in the amount of caries present and also in the eruption time of teeth. The races were similar in the order in which teeth appeared in the mouth. At present an attempt is being made to correlate dental development with the growth of the individual. The preliminary findings indicate a very low correlation, almost negligible, which means that although tooth eruption correlates with

chronological age, it does not necessarily correlate with general body development. Thus, because an individual grows fast in body size it does not mean that his dental development will necessarily be earlier. For this problem, means have been established for various body proportions for each age and sex, as well as the mean eruption time for each tooth for each age and sex, and the above-mentioned correlations are now being made.

SOUTH AMERICAN INDIANS

In 1932 Dr. Steggerda made a survey of statures and cephalic indices of the various Indian tribes of North America. Two years ago a survey was begun, at the request of the Smithsonian Institution, to determine the known anthropometry of South American Indians; and, at present, this study has progressed to include some anthropometrical data on more than 80 different tribes. For some tribes several investigators have contributed data, so that the study includes 132 different investigations on the 80 tribes considered. The general observations deduced from this survey reveal that:

The South American Indians are, on the average, shorter in stature than the North American Indians. Fifteen tribes of those studied show a stature below 155 cm. The greatest number of tribes (43) is found in the stature group 160-164.9 cm. There

were 2 tribes in the group representing statures of from 180 to 184.9 cm., namely the Onas and Tehuelches, both located in the southernmost part of the South American continent.

The range in stature is greater in the South American Indians than in those of North America. In other words, the shortest and the tallest American Indians are to be found in South America. Among the tribes belonging to the shortest stature group we find individuals averaging as low as 145 cm.; on the other hand, the high-stature group includes mean body heights of 184 cm.

Regarding the cephalic index, only 2 tribes show an index under 76 per cent, namely the Chipaya and Alacaluf, the lowest cephalic index having been found in a group of Chipaya males that showed an average of 72.8 per cent. Percentages of 84 and over were found to exist in 13 different tribes, with the Conibos showing the highest index, 91.36. Other body dimensions are being listed for further study, and contour maps are being made to show the geographical location of the various Indians relative to their body proportions.

The review also concerns the hybrid populations of South America. Much is being learned regarding cultural traits, food habits, growth, and development, all subjects which have been studied in detail by Dr. Steggerda for the Maya and Navajo Indians of North America.

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NUTRITION LABORATORY

Boston, Massachusetts

THORNE M. CARPENTER, *Acting Director*

The research program of the Nutrition Laboratory has been affected by the war situation more seriously this year than last year. The defense investigation that was carried on during 1941 was completed on January 1, 1942. Since that time another war study has been started, and again the training of the personnel and the equipment at the Nutrition Laboratory have proved of great aid. Fortunately this latest investigation is resulting in the acquisition of information that will be of scientific value as well as of immediate practical application, for it fits in with the Laboratory's program in opera-

tion since its beginning, namely, the study of phases of the physiology of respiration in relation to respiratory exchange. Some preliminary work has also been done in the way of orientation on several projects that have developed as a result of previous studies in the Laboratory's research program. It is gratifying that, notwithstanding the pressure of the requirements for war research, information is being acquired that will make it possible ultimately, when opportunity offers, to carry on further studies related to the principal objectives of research.

STAFF NOTES

At a meeting of the American Chemical Society at Atlantic City, New Jersey, on September 9, 1941, Dr. T. M. Carpenter presented a paper (jointly with V. Coropatchinsky) entitled "A modified Noyons thermic diaferometer for respiratory gas analysis." This paper was part of a symposium on "New analytical tools for biological and food research." On October 10, 1941, Dr. Carpenter was appointed a member of Section B7c in Division B of the National Defense Research Committee. This superseded his appointment as a consultant in Section L-12 in Division B. On February 6, 1942, he attended as a delegate from the Nutrition Laboratory the Massachusetts Nutrition Conference, which was held at the Massachusetts Institute of Technology in Cambridge, Massachusetts, at the request of Governor Leverett Saltonstall.

For the meeting of the Federation of

American Societies for Experimental Biology, held in Boston on March 31 to April 4, 1942, Dr. Carpenter was Chairman of the Entertainment Committee and Robert C. Lee served on the Personnel Committee.

Dr. Carpenter's annual lecture on basal metabolism was given to the students of the Harvard Medical School on February 27, 1942.

Throughout the year Dr. Carpenter, Robert C. Lee, George Lee, and V. Coropatchinsky have devoted almost their entire time to national defense projects.

Mr. Basil James, a member of the Nutrition Laboratory staff since 1929, resigned on November 19, 1941. Miss M. Joan Blakely acted as laboratory assistant in the metabolism tests on diabetic patients at the New England Deaconess Hospital from June 9, 1941 to November 15, 1941. Miss Jeannette F. Rayner was appointed on

December 8, 1941 to take her place, and has been carrying on the metabolism measurements full time ever since. Miss Charlotte P. Curtis served as laboratory technician, in connection with urine analyses,

from December 3, 1941 to February 14, 1942, and Miss Mary A. Crowley served in the same capacity from March 2, 1942 to May 29, 1942.

INVESTIGATIONS IN PROGRESS

Relation of the rabbit's body composition to its basal metabolism. The chemical analyses of the rabbits that were used for the determination of the basal metabolism of this animal species have been completed. R. C. Lee has had charge of these analyses and has been assisted by G. Lee.

Carbon dioxide in outdoor air. The possibility that there are variations in the carbon dioxide content of atmospheric air, particularly at the earth's surface, has been of immense interest and the object of many studies especially in relation to different atmospheric conditions and to plant growth. With the gas-analysis apparatus and other apparatus thus far available, little evidence has been obtained that there are significant changes in the carbon dioxide content of outdoor air from day to day. The modified Noyons diaferometer, the development of which was completed last year and a description of which was published this year (see p. 222), gives opportunity for much more refined and accurate determinations. During a period of cessation of activities in defense work, preliminary observations were made with this apparatus in a systematic way, to establish whether there are variations in the carbon dioxide content of outdoor air from day to day and at different times of the day. An attempt was also made to construct a volumetric gas-analysis apparatus that would be capable, theoretically, of measuring the carbon dioxide content of outdoor air with an accuracy of 0.001 per cent. After intense effort, however, it was found impossible to obtain results of

this degree of accuracy with this type of apparatus. In a volumetric gas-analysis apparatus a number of factors play a role, namely, changes in barometric pressure, changes in temperature, and changes in the degree of saturation with water vapor. Because of these factors apparently there are physical limits beyond which it is not possible to refine this type of apparatus and have it function accurately to give reliable results. The Noyons diaferometer can be modified with suitable shunts in the galvanometer system so that the carbon dioxide content of outdoor air samples can be determined to within 0.0003 per cent. Observations with this diaferometer have shown that there is some variation in the carbon dioxide content of outdoor air from hour to hour and from day to day. When opportunity presents itself, a systematic investigation is to be carried out with respect to the effects of humidity, barometric pressure, and wind direction on the carbon dioxide content of outdoor air. The construction of the diaferometer and of the volumetric gas-analysis apparatus and the observations with them were carried out by V. Coropatchinsky.

Combustible gases in animal respiratory exchange. In the development of the modified Noyons diaferometer it was found that there was not always good agreement in the oxygen determinations by the diaferometer and by volumetric gas analysis when analyses were made of samples of air collected from respiration chambers in which animals had been breathing. This pointed to the possible presence of an un-

known gas in the respiratory exchange of animals, in addition to the known gases nitrogen, carbon dioxide, and oxygen. Preliminary observations have been made this year with respect to the presence of a combustible gas in the respiratory exchange of the cat. When a gas-analysis apparatus adapted for the determination of combustible gases was used, it was found that there is a definite trace of a combustible gas in this animal's respiratory exchange. These observations will be continued when opportunity presents. This finding illustrates one of the weaknesses of the diaferometer system, namely, that when another gas is present in an air sample in addition to those ordinarily present in atmospheric air, the oxygen determinations with the diaferometer are not reliable. On the other hand, it shows one of the advantages of the diaferometer in helping in the detection of unknown gases in respiratory exchange. The observations with the cat were made by George Lee.

Metabolism in diabetes mellitus. The respiratory exchange measurements on diabetic patients have been continued this year through the special grant from the Carnegie Institution mentioned last year, and with the cooperation of Research Associate Dr. Elliott P. Joslin, Medical Director of the George F. Baker Clinic of the New England Deaconess Hospital. The tests were made on 207 days and included 146 patients. The various phases of the investigation have included measurements

of the basal metabolism of each patient on one or more days and, on 116 days, observations regarding the effect on the respiratory quotient of administration of 50 grams of dextrose. Comparisons were made between the effects of the oral and the intravenous routes for administration of this sugar, and in a few cases insulin was given along with the sugar. With 14 patients comparisons were also made of the effects of ingestion of 50 grams of dextrose and of levulose. A study was made of the changes in the respiratory quotient after administration of dextrose with patients in diabetic coma, during severe acidosis, and during recovery from acidosis, with patients showing resistance to insulin, and with a few during insulin reaction. Charts showing the combustion of carbohydrates in patients of different types were prepared and exhibited at the annual meeting of the Massachusetts Medical Society in Boston on May 25 to 27, 1942, and at the meeting of the American Medical Association in Atlantic City, New Jersey, on June 8 to 12, 1942. At the latter meeting a special certificate of merit was awarded to the exhibit on diabetes mellitus, in which these charts were included. The investigation has been pursued this year on a full-time basis with the active cooperation of Dr. Howard F. Root. The respiratory exchange measurements were made by B. James, M. J. Blakely, G. Lee, and Jeannette F. Rayner.

PUBLICATIONS

- (1) *Heat production of the rabbit at 28° C. as affected by previous adaptation to temperatures between 10° and 31° C.* Robert C. Lee. Jour. Nutrition, vol. 23, pp. 83-90 (1942).

Twelve adult rabbits lived for stated periods at a given temperature between 10° and 31° C. They were then kept at 28° and

without food for 24 hours, and immediately thereafter their oxygen consumption was measured at 28° C. The heat production, calculated from the oxygen consumption as thus measured, was compared with the *basal* heat production of each rabbit predicted from its body weight. Five rabbits, after living for 7 weeks at 17° C., had a heat production aver-

aging 19.0 per cent above their average predicted basal level. Their minimum heat production (7 per cent below basal) was found when they had been living for 3 weeks at 31° after a gradual approach from lower temperatures to this temperature. Seven other rabbits that lived for 9 weeks at 10° and later for 8 weeks at 29° C. showed deviations from basal of +17.0 and -1.5 per cent, respectively. Adjustment to increase in temperature occurred in a shorter time than adjustment to decrease in temperature. The major adjustment to increase in temperature toward thermic neutrality occurred in 2 to 3 weeks, but further adjustment continued for at least 2 months. In studies concerning the effect of any superimposed condition on basal metabolism, rabbits should be kept at 28° to 29° C. for 3 weeks prior to measurements, and their metabolism should be measured at this same temperature.

- (2) *A modified Noyons thermic diaferometer for respiratory gas analysis.* Thorne M. Carpenter and Vladimir S. Coropatchinsky. Indus. and Engin. Chem., Anal. Ed., vol. 14, pp. 159-163 (1942).

This modified diaferometer was designed primarily for analysis of respiratory chamber air. The apparatus has two parallel pathways for two continuous streams of air, which are driven through absorbents for both carbon dioxide and water vapor or through an absorbent for water vapor alone. After passing through the absorbents, portions of the two streams of air are aspirated by a constant-level hydrostatic pump through chambers containing platinum resistance wires. These wires form two arms of a Wheatstone bridge system. The differences in the cooling powers of the gases passing through the two sides of the system are measured by the deflections of a delicate galvanometer. The apparatus has been standardized by comparisons of analyses of diluted respiratory air and analyses of atmospheric air, and constants have been established for the equivalent percentages of carbon dioxide content and oxygen deficit in samples of respiratory chamber air per millimeter deflection of the galvanometer. The total time required for analysis

of an air sample for both carbon dioxide content and oxygen deficit is about 17 minutes; the total volume of sample required for the complete analysis is 1 liter. Forty-six consecutive alcohol control tests on 5 days gave an average respiratory quotient of 0.662, with a standard deviation of ± 0.0084 . The standard deviation of the quotients from the theoretical alcohol quotient of 0.667 was ± 0.0097 .

- (3) *The respiratory quotient of protein of the Dalmatian dog.* Thorne M. Carpenter and Harry C. Trimble. Jour. Nutrition, vol. 23, pp. 345-349 (1942).

The respiratory exchange of an adult, female Dalmatian dog was measured in two series of experiments 11 months apart, either after several days of fasting or at varying lengths of time after ingestion of different amounts of casein or raw beef. The urine was collected by catheterization. Most of the nonprotein respiratory quotients were below 0.71. This finding could not be ascribed to errors in measurement, to formation of sugar from protein, or to excretion of uric acid, which is greater in this dog than in dogs of other breeds. As the urine did not show any signs of acidosis by a qualitative test and as the percentage of ammonia in relation to the total urinary nitrogen was not high enough in any case to indicate the presence of acidosis, it was assumed that the combustion of fat was normal. The respiratory quotients of protein, calculated on the assumption that the fat metabolism was normal, were all well below 0.81. The hypothesis is advanced that the respiratory quotient of protein of the Dalmatian dog, although varying with the condition of the animal with respect to fasting and ingestion of food, is lower in general than the usually accepted respiratory quotient of protein, 0.81.

- (4) *Carbohydrate combustion in human subjects after oral and after intravenous administration of dextrose.* Howard F. Root and Thorne M. Carpenter. Arch. Internal Med., vol. 69, pp. 997-1004 (1942).

With four normal men, post-absorptive and sitting, the respiratory exchange was meas-

ured in three consecutive 10-minute periods. The men were then given 50 grams of dextrose by mouth or intravenously, and the measurements were continued for nine consecutive 15-minute periods. Samples of blood and urine were collected at intervals during the tests. The blood sugar was higher $\frac{1}{2}$ hour after and lower 1 hour after intravenous injection of the dextrose than it was at the same times after oral administration, but

there was no difference in the values after $2\frac{1}{2}$ hours. Sugar appeared in the urine only after intravenous injection. The increases in respiratory quotient, oxygen consumption, and carbohydrate combustion for $2\frac{1}{2}$ hours after administration of the sugar were practically the same whether the sugar was given by mouth or by vein. There was a tendency for the increases to be insignificantly greater after oral administration.

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COROPATCHINSKY, VLADIMIR S. See CARPENTER, THORNE M.

LEE, ROBERT C. Heat production of the rabbit at 28° C. as affected by previous adaptation to temperatures between 10° and 31° C. *Jour. Nutrition*, vol. 23, pp. 83-90 (1942).

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TRIMBLE, HARRY C. See CARPENTER, THORNE M.

SPECIAL PROJECTS: BIOLOGICAL SCIENCES

W. E. CASTLE, University of California, Berkeley, California. *Experimental studies of heredity in small mammals*. (For previous reports see Year Books Nos. 3 to 38 and 40.)

The investigations of the past year have been restricted to a further study of the linkage relations of genes of the rat (*Rattus norvegicus*). Several new mutant genes have been received from various laboratories where the mutations have been discovered among closely bred stocks used in nutritional, pathological, or psychological studies. It is generally known that Dr. Helen Dean King and Dr. Castle have been studying linkage in the rat for some years and have accumulated a nearly complete assemblage of the known mutant genes of the rat. This knowledge has inclined rat investigators not interested primarily in genetics to call Dr. Castle's and Dr. King's attention to promising genetic material which comes to their notice but which they are not in a position themselves to utilize. This kindly cooperation and the donation of genetic stocks are greatly appreciated.

One of the most interesting of the new mutants was discovered and described in the *Journal of Heredity* in 1941 by Dr. R. O. Greep, of the Squibb Laboratories at New Brunswick, New Jersey. It is called *incisorless*, for the two pairs of incisors, which characterize the entire family of rodents and are of such functional importance to them in obtaining food and as weapons of offense and defense, are entirely wanting in this mutant race. They are a kind of gnawing animal which no longer can gnaw. They are able to eat only soft or pulverized food. In competition with normal rats they would quickly perish in a state of nature. The mutation is a recessive in heredity and so true-breeding

from the start. From a single albino male which carried the mutant gene as a recessive but was entirely normal himself, having incisors as ordinary albino rats do, it has been possible to obtain numerous incisorless young among his second-generation descendants. It has also been possible to ascertain very promptly in what chromosome the gene is borne. The latter shows very close linkage with the gene *curly*, which lies at one extremity of the second chromosome. The crossover percentage with curly is apparently less than 1 per cent. There is another mutant gene also closely linked with curly, namely *anemia*, with about 2 per cent of crossing over with curly. Crosses are now being made to ascertain the order of the three genes, which must be either *Cu in an* or *in Cu an*. This same second chromosome carries also the gene for brown pigmentation, which lies toward the opposite end of the chromosome. Thus we now have 4 genes in the second linkage group, and 5 in the first (albino) linkage group, both being presumably in long chromosomes, 40 or more linkage units long.

Loss mutations such as incisorless are of much interest in their possible relation to evolution. In the rat loss of incisors would be fatal in a state of nature, but in other mammals it is conceivable that such a loss would be advantageous. Getting rid of a useless organ is no less profitable in evolution than acquiring a new and useful one. Paleontologists tell us that the early proboscids had a pair of incisors both above and below, like those of rodents but more tusklike and project-

ing straight forward. They were probably used in digging for roots or tubers. Later the tusks of the lower jaw disappeared completely and only the tusks of the upper jaw remained, as in the extinct mammoths and the living elephants. It seems probable that the tusks of the lower jaw were lost by a single mutation like that of the incisorless rat, it being advantageous that the size and functional importance of the remaining pair of tusks be increased, and the other pair, now a mere encumbrance, be lost.

Another loss mutation which proved advantageous probably occurred in the ancestral history of man, namely, loss of hair over most of the body. Other anthropoids have a complete hairy coat. Doubtless our ancestors also had such a coat. A hairless mutation in a tropical environment would probably be no handicap to man, but positively advantageous in relation to body parasites and protection from the heat, and man had sufficient ingenuity to devise clothing and seek out caves for protection from cold. Hairless mutations are of frequent occurrence in our laboratory animals. They have been obtained and their inheritance has been studied in rats, mice, and rabbits. In each case the loss mutation is a simple recessive in its inheritance. In man the supposed earlier

hairiness has been completely lost. There are no hairy humans except by an occasional possible reverse mutation, which is advantageous only for sideshow exploitation.

We now have 19 rat genes to work with. Eleven of these are borne in three chromosomes, constituting linkage groups I-III. Group I includes albinism, red-eyed yellow, pink-eyed yellow, waltzing, and Grüneberg's lethal. Group II includes curly, incisorless, anemia, and brown. Group III includes hairless and wobbly. Unassigned as yet to linkage groups are agouti, blue, curly₂, jaundiced, kinky, hydrocephalus, cataract, and epilepsy. The last three are recent acquisitions as yet imperfectly studied, and whether they will prove available for linkage studies remains to be demonstrated.

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PAUL S. CONGER, United States National Museum, Washington, District of Columbia. *Investigations and preparation for publication of results of studies on Diatomaceae*. (For previous reports see Year Books Nos. 18 to 40.)

The work on diatoms during the past year centered largely on the continuation of several projects previously in progress, involving considerable investigation concerning the ecological and oceanographic importance of diatoms. This included a large amount of bibliographic work and organization of information with a view to making it more readily available.

The advent of the war necessitated a considerable diversion to preparation of the rarer and type parts of the collection, and of certain irreplaceable materials for quick removal in case of imminent need.

The needs of the war resulted in a number of unexpected and important developments involving diatomaceous materials or the methods of diatom research,

and requests for information from both the Army and the Navy were answered, as well as materials examined. A number of these matters are strictly applicable to the present emergency, but in one or two instances there is promise of large-scale permanent benefits.

General requests for information and inspection of materials during the year seemed correspondingly increased, diatomaceous materials finding a number of new and special uses. Particularly noteworthy were requests for information on culture of diatoms to be used in physiological and other investigations. Of special interest were identifications made for Dr. Harold J. Humm, of the Duke University Marine Biological Laboratory, in connection with his pioneering studies of the biological and chemical transformations on the beaches at Beaufort, North Carolina. Beaches constitute one of the most biochemically active and significant of all ecological environments, and the diatoms are one important factor in the transformations that take place.

Identifications were made for Dr. John Watson, of the Physics Department of the University of Toronto, in connection with investigations of the electron microscope, now published. New records of soil diatoms for the United States were included in identifications made for Dr. Arlo Smith, of the Texas Technological College. Work was continued on examination of diatoms of the Second Byrd Antarctic Expedition.

The course on diatoms, covering their biological, oceanographic, and economic importance, conducted for a number of years at the Chesapeake Biological Laboratory was temporarily discontinued in the summer of 1942 owing to war conditions.

In the course of investigation of the diatomaceous sediments of a 10-acre lake near Solomons Island, Maryland, a new and simple method was developed, and considerable work was done on what appears to be a very interesting and practically unstudied field, that of the ebullition of gases of decomposition from lake waters. This process is important in the decomposition of lake-bottom sediments, which results in the concentration of their diatomaceous constituents through the removal of the other materials, and it is also important in the rapid transformation and release of subsequently usable substances. The simple device developed for collection of such gases consisted of an inverted graduated tube sealed at its upper end, filled with water, and placed with its lower end passed through a supporting float and connected with a collecting funnel. As released gas bubbles arose they replaced water in the upper end of the tube, giving a daily reading of the amount of gas formed in a given area. By means of a number of these collectors anchored about the lake, the average production of a highly inflammable gas, apparently mostly methane, was found to be 90 cubic feet per acre per day in August, or 900 cubic feet over the whole lake per day. A report of the various aspects of this study is in preparation. The writer had previously experienced heavy gas production from other dried diatom sediments through destructive distillation. Examinations of the muds at different depths showed decided changes accompanying this process.

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TH. DOBZHANSKY, Columbia University, New York, N. Y. *Studies on the genetic structure of natural populations.* (For previous reports see Year Books Nos. 37 to 40.)

The course of biological evolution can be likened to a manufacturing process which involves three stages. The first stage is the production of raw materials, that is, of heritable variants. The heritable variants (gene changes and chromosomal aberrations) accumulate to a greater or lesser extent in natural populations of any living species. The presence of these variants, however, does not in itself guarantee that evolutionary changes will take place, just as the mere availability of raw materials in a factory does not guarantee the end product of the manufacturing process. The second stage entails a series of processes which combine the variants into organized systems, which are the hereditary endowments of new races and species. By analogy, the raw materials are thus molded into factory products. This is the part of the evolutionary process least understood. Finally, the third stage consists in the development of isolating mechanisms and the fixation of the nascent species. This stage can be compared to the packaging of the manufactured articles.

The origin of heritable variants is the most fundamental problem of the biologist in his attempt to understand the mechanics of evolution. This problem is being studied within the Department of Genetics of the Carnegie Institution of Washington by the group of investigators headed by Drs. M. Demerec and B. P. Kaufmann. The program of research which deals with the genetic structure of natural populations is the logical continuation of these studies. Inasmuch as it is established that new heritable variants arise from time to time in natural populations, their subsequent fate must be ascertained. This problem is, in turn, twofold: (1) the qualitative and

the quantitative composition of the accumulated store of heritable variants must be described, and (2) their reactions to the various agents which impinge upon them must be clarified. The first is the static and the second the dynamic aspect of population genetics. For several years past, investigations which bear upon both aspects have been carried on simultaneously, the fly *Drosophila pseudoobscura* serving as the test material. At present the work on the statics of natural populations is approaching completion. By "completion" it is not meant that the topic has been exhausted; the writer is conscious of the many deficiencies in the available information. The data as they now stand are, however, adequate for a general outline of the situation, and from now on it appears more profitable to concentrate on the dynamic aspect.

Genetic variability accumulated in natural populations. *Drosophila pseudoobscura* collected anywhere in its species area from British Columbia to Guatemala is singularly uniform in its structural characters. The observed variation is chiefly in the size of individuals, and most of this variation is nonhereditary. Only very seldom are individuals which display obvious hereditary variants found. For example, among the thousands of wild flies which have been observed at Idyllwild, Mount San Jacinto, California, during the summer of 1942, the only noteworthy variants were several specimens with a brighter than normal eye color.

This impression of uniformity is completely reversed if, with the aid of special genetic techniques, individuals homozygous for different wild chromosomes are obtained. A majority of wild specimens

carry various mutant genes in heterozygous condition. Some classes of mutant genes are amenable to exact quantitative estimation of their frequencies. Thus, it has been determined that in the wild flies which inhabit Mount San Jacinto, 21.3 ± 1.8 per cent of the second, 13.9 ± 1.6 per cent of the third, and 25.5 ± 2.2 per cent of the fourth chromosomes contain recessive mutant genes which are lethal or semilethal to homozygotes. Since every fly carries each of the above chromosomes in duplicate, it can be computed that only about 25.5 per cent of the wild individuals are free of lethals and semilethals; 39.4 per cent have one, 25.0 per cent two, 8.3 per cent three, 1.5 per cent four, 0.14 per cent five, and 0.01 per cent six lethals or semilethals concealed in their germ plasms (these figures replace the preliminary estimates given in Year Book No. 40).

Furthermore, the chromosomes of many wild individuals carry recessive genes which, when homozygous, reduce the viability of their carriers to an extent which is perceptible but not sufficiently deleterious to be classed as semilethal. Quantitative estimation of the frequencies of such genes presents serious technical difficulties because the magnitude of their effects varies from semilethality to a barely detectable constitutional weakness. The best estimates available are that 21.1 ± 2.3 per cent of the second, about 30 per cent of the third, and about 41 per cent of the fourth chromosomes contain genetic modifiers which are to some extent deleterious to viability. Making the necessary computations, we find that only 10.6 per cent of the flies in the natural populations are likely to be free from chromosomes which carry deleterious modifiers, and that 29.5 per cent will carry one, 33.3 per cent two, 19.6 per cent three, 6.2 per cent four, 1.0 per cent five, and 0.06 per cent six such chromosomes. It is apparent therefore that

perhaps no more than 2 per cent of the flies can be expected to be entirely free of lethals, semilethals, and deleterious modifiers of lesser degrees. Moreover, genes, most if not all of which are recessive, which modify the development rate of their carriers are even more widespread in natural populations than the viability modifiers just mentioned. A majority of these genes act, when homozygous, to slow down development, but some of them, on the contrary, accelerate it. In wild populations about 54 per cent of the second and 35 per cent of the fourth chromosomes contain detectable modifiers of the development rate; no estimate for the third chromosomes is available. About 13 per cent of the second and 8 per cent of the fourth chromosomes contain recessive factors which produce sterility of one or both sexes in the homozygotes. Finally, between 1 and 5 per cent of the second, third, and fourth chromosomes contain recessive genes which produce various effects on the visible morphology of the fly (these figures replace the preliminary ones in Year Book No. 40).

A theory of hybrid vigor. It is well known that inbreeding and consanguinity frequently result in deterioration of the stock, and that outbreeding is followed by so-called hybrid vigor or heterosis. These phenomena are clearly of importance in agriculture, as witnessed, for example, by the increased corn yield which is obtained by hybrid-corn plantings. Their sociological implications are probably also important. For more than two decades the degeneration which follows inbreeding and the increase in vigor which follows crossing have been ascribed, respectively, to homozygosis of concealed recessives and to masking of the latter by beneficial dominants. The results of analysis of wild populations of *Drosophila pseudoobscura* support this theory and permit further insight into the nature of heterosis. The

great majority of the recessives found in the chromosomes of the fly are deleterious when homozygous. Moreover, very few of the flies in natural populations are "normal" in the sense that they carry no concealed recessives capable of producing some kind of deleterious effect. The apparent uniformity of the individuals found in nature is basically a function of a great variety of chromosomes with *different* recessive mutants. Recessives may become homozygous and thus manifest themselves, chiefly through consanguinity. But the frequency of consanguineous matings depends on the effective size of the population and the variety of chromosomes it contains. The phenomena of heterosis depend therefore on the population structure of the species. The process of mutation constantly produces new genetic variants presumably in all species, and a majority of these variants are deleterious. The dominant and semidominant mutants are eliminated with relative promptness, hence the dominant alleles are in general more beneficial than the recessive ones. The recessive mutant alleles accumulate in the populations until their frequencies become sufficiently high so that homozygotes are produced at a rate which counterbalances the mutation frequency. The point at which the mutation is counterbalanced by elimination, in other words the equilibrium point, is a function of the breeding structure of the species. In species which reproduce by self-fertilization, the genetic variants become homozygous and subject to elimination by natural selection very soon after their origin. In such species the accumulation of concealed deleterious recessives will be small, and little if any heterosis will be observed, since only genes with very mild deleterious effects can become established in any one strain. The same situation is expected to obtain in species characterized by very small effec-

tive population size. In species with a greater effective population size, many chromosomes will contain deleterious recessives. Inbreeding in such species will be distinctly deleterious and outbreeding beneficial, but inbred strains which would equal in vigor the outbred strains could be produced by careful selection. *Drosophila pseudoobscura* probably falls in this category. Finally, in species with very large population sizes, most if not all chromosomes will accumulate deleterious recessives. In fact, since the effect of natural selection in such species is limited almost entirely to heterozygotes, a condition might arise in which most of the genes would be represented by a multitude of alleles, most or all of them deleterious in homozygous condition. The phenomena of heterosis would be most pronounced in such species, and no amount of selection would suffice to produce a fully vigorous inbred strain. Cultivated maize is probably an example of this last category of species. Because of a lack of appreciation of their importance, however, studies on population structure in maize and other cultivated species have been neglected by agriculturists, and no decision can be reached at present concerning this subject.

Concealed variability as a source of potential evolutionary changes. The multitude of recessives known to be carried in natural populations in a concealed condition may constitute the raw materials of possible evolutionary changes. But the fact that the great majority of mutants are deleterious to their carriers offers a real obstacle to the acceptance of this view. The difficulty is resolved, at least in theory, by supposing that a mutant which is deleterious in a certain environment and in combination with certain other genes may be neutral or even beneficial in other environments and in combination with other genes. Experiments are in progress to test

the validity of this supposition, which, unfortunately, rests on speculation rather than factual data. The preliminary results can now be outlined as follows.

Some second and fourth chromosomes from wild populations of *Drosophila pseudoobscura* contain recessive mutants which, when homozygous, produce deteriorations of viability, modifications of the development rate, and other changes (see above). Stocks of flies with such chromosomes have been preserved to serve for further experiments. Homozygotes for these chromosomes are raised at three different temperatures (16.5° , 21° , 25.5° C.) and at different degrees of crowding. A technique is used whereby the homozygotes are made to develop in the same cultures with sibs known to have the standard viability, development rate, etc. The chromosomes so tested display a variety of behaviors. Some chromosomes show essentially the same degree of viability at all the temperatures and at all degrees of crowding tried; the viability of other chromosomes is best at the lowest temperature and deteriorates at the higher ones; still others do best at the intermediate temperature; but none which prefer the highest temperature have so far been detected. At the same time, some homozygotes show the best viability in sparsely populated cultures, others in crowded ones. The viability of a heritable variant is therefore not an unalterable characteristic, but a function of the environment. The modifiers of the development rate have, thus far, behaved more stably. In other experiments, the chromosomes to be tested (a majority of which came from populations inhabiting Mount San Jacinto, California) are, by means of a series of crosses, placed onto the genetic backgrounds of unrelated strains. Strains derived from different parts of the distribution area of the species, a fairly large collection of which is being kept in the

laboratory, are used for this purpose. The outcome of these experiments cannot be reported as yet, but some data already obtained suggest that the same genetic variant may behave differently on different genetic backgrounds.

It is known that certain rare chromosomes, isolated from natural populations, when tested in homozygous condition have produced not a lowering of viability but an increase (see Year Book No. 40). Several such chromosomes have been included in the sample which has been exposed to different temperatures and different degrees of crowding, but not one has maintained its superior-to-normal record in all the conditions studied. It may be regarded as certain that the species contains genetic variants which are superior to the average norm under certain special conditions; but the same variants are inferior to the norm in other, and presumably more prevalent, environments. The interest of these findings is obvious. Variants of the above kind may be regarded as a safety valve maintained by the species against the contingency of environmental change. It is also possible that the species contains at all times a variety of genotypes, some of which are optimal under some and others under other conditions of the environment to which the species is normally exposed in the course of the seasonal cycle and in different microclimatic and microecological niches. If this surmise is correct, the genetic composition of the species must be in a constant flux. Indeed, natural selection would strive so to change the species genotype as to bring it up to the highest attainable optimum. But if the environment should change very rapidly in relation to the speed of reproduction of the organism, the latter might find itself always close to but never quite at the optimum goal. Data indicating that such a state of flux actually obtains in natural

populations of *Drosophila pseudoobscura* are available (see Year Book No. 40 for a preliminary report; a systematic collection of such data continues).

Chromosomal variants. Aside from the inheritable variants of genic nature, variations in the arrangement of genes in the chromosomes are also found in natural populations of *Drosophila pseudoobscura*. This phenomenon has been studied for about six years; the results are described in a small monograph now in preparation. For unknown reasons, the gene arrangement is far more variable in the third than in the other chromosomes. The variants are inversions of chromosome sections. In the third chromosome, at least nineteen different gene arrangements are known. Their geographic distribution has been traced in so far as the material available would permit. Their phylogenetic relationships have been established. At first sight, the geographic distribution pattern of the different gene arrangements appears extremely complex and irregular. Professor Carl Epling, of the University of California at Los Angeles, who has kindly consented to examine the pertinent data, has come to the conclusion, however, that an explanation of these complex distribution patterns may be sought in the history of the species in connection with the geologic history of its environment, particularly that of the floras of the Tertiary period. The striking, and altogether unexpected, inference reached by Professor Epling is that at least the phylogenetically basic arrangements existed in geologically rather remote times, as far back as the Oligocene, or even earlier.

An attempt to determine the order of magnitude of certain basic constants of population dynamics. The evolutionary fate of a species is determined in part by its intrinsic properties, its breeding structure, and in part by the environment in

which it lives. Among the intrinsic properties, the following seem most important: (a) A species with high mutation rates will, in general, be more plastic than a species whose genes are more stable. The mutation rate of a gene is expressed by its mutability coefficient, v . (b) A large undivided species in which the genes diffuse freely throughout the distribution area is less likely to differentiate into subspecies than a species split up into local colonies exchanging individuals (migrants) at a low rate. The rate of exchange of individuals between a colony and the rest of the species is symbolized by the migration coefficient, m . (c) A species with an effectively large panmictic population is evolutionarily more rigid than one with locally limited population sizes; the genetically effective population size is expressed by the Wright's constant, N . (d) Deviations from randomness of mating, for example frequent brother-sister mating, may upset the genetic equilibrium expected in a panmictic population. The degree of departure from randomness of mating may be expressed by the inbreeding coefficient, F .

The lethals and semilethals present in natural populations constitute, for several reasons, favorable material for studies on population dynamics. Lethals found in natural populations may be alleles because (a) lethal mutations of the same gene may arise recurrently at different times and in different places, and because (b) the progeny of a single mutant may increase and spread. Independently arisen lethals and lethals of common origin may be distinguished. In a large undivided species there should be no difference in the incidence of alleles among lethals found within a small territory and among those collected in remote territories. In such a species every lethal is expected to attain its highest possible equilibrium frequency

in every part of the distribution area. Conversely, restriction of the effective population size and migration barriers will cause the frequency of alleles among lethals within a small territory to be higher than that among lethals found in remote territories. Indeed, allelic lethals found in remote territories are independently arisen ones, whereas within a small territory both independent lethals and lethals of common origin will be found.

The lethals and semilethals in the third chromosome of *Drosophila pseudoobscura* have been chosen for detailed examination. Samples of lethals were taken at several collecting "stations" on Mount San Jacinto and in the Death Valley region, California. A "station" is a territory of at most 100 yards in diameter. The stations on Mount San Jacinto are grouped in three "localities"; the distances between stations in a locality are from $\frac{1}{8}$ mile to 2 miles. The distances between the localities are from 10 to 15 miles. Mount San Jacinto is more than 200 miles distant from the Death Valley region. The frequencies of allelism among lethals recovered from various population samples have been determined (see preliminary data in Year Books Nos. 38 and 39). The most important fact is that the frequency of alleles among lethals coming from different localities and regions is only 0.413 ± 0.081 per cent, whereas among lethals within a station it is as high as 2.13 ± 0.32 per cent. It is clear that *Drosophila pseudoobscura* is a species differentiated into local colonies which differ in genetic constitution.

A mathematical analysis of the above data has been made by Professor Sewall Wright, of the University of Chicago. The conclusions are, briefly, as follows: It is reasonable to assume that the allelic lethals found in different localities and regions are almost entirely of independent origin. The frequency of alleles among independent

lethals is a function of the number of loci (genes) in the chromosome capable of producing lethals by mutation. On the assumption that the mutation rates are uniform for all loci, and that the lethals produce either no effect or a uniform effect on viability in heterozygotes, the number of lethal-producing loci in the third chromosome of *Drosophila pseudoobscura* turns out to be 285 (this figure is to replace the former estimate, 250, given in Year Book No. 38). If the above assumptions are not granted, the number of the loci is greater than 285, which is, hence, the minimum estimate. A maximum estimate, arrived at by a different method, is approximately 1100, but for our purposes the minimum estimate is preferable.

Knowing the incidence of third chromosomes carrying lethals in natural populations and the number of mutable loci, it can be computed that the average frequency of a lethal in the populations of Mount San Jacinto is approximately 5.23×10^{-4} , or 0.0523 per cent. Similarly, knowing the rate of origin of new lethals by mutation (see Year Book No. 38) and the number of lethal-producing loci, we find that the average mutation rate per locus per generation is $\nu = 1.077 \times 10^{-5}$. Now, in a population of a very large effective size the equilibrium frequency of an autosomal recessive lethal must approach the square root of the mutation rate producing that lethal. The observed frequency of lethals is much smaller than would be expected in such a population. This discrepancy may be brought about by one or by a combination of several causes. Among these causes, deviation from randomness of mating (F) and a possible deleterious effect of the lethals in heterozygotes (expressed by a selection coefficient, s) may be important. There being no way to differentiate between the effects of F and s on the basis of the avail-

able data, only a joint estimate of the value $F + s$ is possible. For the populations of Mount San Jacinto this is close to 0.018.

The observed difference between the frequencies of alleles among lethals found within a station on one hand and those found in remote localities and regions on the other is produced by a restriction of the effective population size (the Wright's constant, N) and a limitation of interchange of individuals between populations inhabiting different territories (m). Again, the data do not permit rigorous discrimination between these variables. In view of the now known relatively high mobility of *Drosophila pseudoobscura* flies (see Year Book No. 40), however, it may be assumed that there is a fairly free interchange of germ plasms between populations inhabiting different stations within a locality on Mount San Jacinto. The value m for stations within a locality is assumed to be about 0.5, which is large enough to give no appreciable isolation. If so, the Wright's constant for a station is in the neighborhood of 50. The mobility of the flies is, however, not high enough to permit an appreciable migration from locality to locality. Assuming m for localities to be less than 0.01, the value of N for the largest locality on Mount San Jacinto (about 6 million square meters) is probably between 20,000 and 30,000.

The results reported in the foregoing paragraphs show how important it is to secure reliable information on the migra-

tion rates of *Drosophila pseudoobscura* in its natural habitats. A series of experiments designed to clarify this problem have been conducted in summers of 1941 and 1942 on Mount San Jacinto, California (see a preliminary report in Year Book No. 40). The experiments carried out in 1942 were more successful than those of 1941. The analysis of the resulting data will, however, require some time; it is hoped that the conclusions will be ready for presentation in the next annual report.

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CHARLES ELTON, Bureau of Animal Population, Oxford University, Oxford, England.
Research on natural fluctuations in North American animal populations. (For previous reports see Year Books Nos. 37 to 40.)

The grant of the Carnegie Corporation of New York, through the Carnegie Institution of Washington, has again ensured the continuity of research into fluctuations

in North American animals, although wartime research is now the main occupation of the Bureau of Animal Population. Mrs. Mary Nicholson has helped Charles Elton

to finish a paper on the lynx cycle in Canada and has done the mapping for the two annual Canadian Wild Life Enquiries. The lynx paper, together with an earlier one on the muskrat, are the end products of part of a series of researches, begun in 1925, which have involved not only the accumulation of annual reports through the Hudson's Bay Company, but an examination of fur returns back to the eighteenth century. Both species show a well marked ten-year cycle covering a huge area. Peak years are not always synchronous: in the lynx, abundance is reached and passed first in the northwest, some two or three years before other parts of Canada.

Charles Elton's book *Voles, mice and lemmings: problems in population dynamics* (see bibliography) includes a great body of new data on fluctuations in North American animals: in particular, on the short cycle in colored and arctic fox in the eastern Arctic and Subarctic.

The "Canadian Arctic Wild Life Enquiry, 1940-41," by Dennis Chitty and Mary Nicholson, is in press. The year was remarkable for an almost universal improvement in arctic fox populations. "The Snowshoe Rabbit Enquiry, 1939-40" was published early in 1942, and the reports for 1940-41 have been mapped, but not yet published. A continent-wide increase in snowshoe rabbits was still continuing, and the regional occurrence of "crashes" is to be expected in the next few years.

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ARTHUR T. HERTIG and JOHN ROCK, Boston Lying-in Hospital, Boston, and Free Hospital for Women, Brookline, Massachusetts. *Research in embryology, embryological pathology, and reproductive physiology*. (For previous reports see Year Books Nos. 36 to 40.)

These studies on various early aspects of human reproduction have been continued with the financial support of the Carnegie Institution of Washington and in cooperation with its Department of Embryology. In addition, as in the past four years, Dr. Rock has received aid from the William F. Milton Fund of Harvard University.

Since the last report, the authors have succeeded in obtaining four more stages of early human development, three of them normal and the fourth pathological. Two of the normal fertilized ova are younger than any thus far obtained, and shed light on the critical period immediately following implantation of the human blastocyst.

These two stages are $7\frac{1}{2}$ and $9\frac{1}{2}$ days of age respectively. The third normal specimen is approximately 11 days of age and is intermediate in development between the two normal ova of 11 and 12 days, whose description has been published since the report in Year Book No. 40 (see bibliography).

In this study thus far, twelve early human ova have been recovered from uteri removed surgically prior to the first missed menstrual period. Seven of these specimens are normal and five pathological. Sixty-one hysterectomy cases have constituted the clinical material which has yielded these specimens, an incidence of

pregnancy in this group of approximately 20 per cent. This fact as well as other clinically important features, such as the probable time of nidation and the location of embedment, were presented at the annual meeting of the American Gynecological Society, June 1942. From these studies it is concluded: (1) that ovulation occurs approximately 14 days prior to the next expected menstrual period and (2) that nidation takes place at a variable stage of development of the blastocyst, on an endometrium which may vary in phase from the 19th to the 22d day. Furthermore, it was found that the seven normal conceptuses were implanted on the posterior wall of the uterus (without correlation as to the proximity of the corresponding active corpus luteum), whereas the abnormal ova were all on the anterior wall. Whether further specimens will make this distribution more apparent than real is problematical, but at least it is an interesting observation.

Much of this material was presented to the American Association of Experimental Pathologists in April 1942. The controlled experimental features of the study were stressed and the high proportion of pathological ova (42 per cent) was pointed out. This study indicates that the incidence of pathological ova is higher than the accepted incidence of spontaneous abortion of clinically diagnosed pregnancies (about 10 per cent) and brings the results more in line with the high incidence of pathological pregnancies in the lower animals (30-45 per cent).

The corpora lutea of these early pregnancies are being studied morphologically and a paper is being prepared for publication. It has been found that the normal fatty degenerative changes in the corpus luteum of menstruation are prevented from appearing at the usual time (23 days). This phenomenon is undoubtedly

correlated with the implantation of the ovum and its effect, either direct or indirect, on the corpus luteum.

A description of the new 11-day ovum was presented before the American Association of Anatomists in April 1942. At that time the point was stressed that the endometrium can be in a variable stage of development at the time of nidation, since we possess two 11-day ova of approximately equal development whose endometria are 2 to 3 days apart in their respective stages of secretory development. This biological variation has been confirmed and amplified in the subsequent finding of the 7½- and 9½-day ova, the endometrium of the latter being significantly older than that of either of the 11-day specimens. Hence, a given blastocyst can implant on secretory endometrium which may vary from the 19th to 22d day in its secretory development, as mentioned above.

Under the direction of Dr. Rock, the work on human ovarian ova has continued, with the chief objective of eliciting *in vitro* fertilization. Modifications of procedure during the past year have consisted in: (1) *en masse* culture of six to twelve eggs instead of manipulation of individual ova; (2) insemination in Locke solution after repeated washing of the ova; (3) varying the time intervals of pre-insemination and of post-insemination culture; (4) repeated changing of the culture medium after insemination in order to avoid infection.

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ELLIOTT P. JOSLIN, New England Deaconess Hospital, Boston, Massachusetts. *Studies of carbohydrate metabolism in diabetes at the New England Deaconess Hospital.* (For previous report see Year Book No. 40.)

During the past year, observations on diabetic patients have been continued at the George F. Baker Clinic of the New England Deaconess Hospital, utilizing the apparatus for determination of the metabolic rate and respiratory quotient provided by the Nutrition Laboratory of the Carnegie Institution of Washington.

Patients in acute acidosis and particularly during recovery from acidosis have been specially studied. In addition, problems connected with the efficiency of insulin action in relation to carbohydrate utilization have been investigated owing to the presence in the hospital of a number of patients illustrating various aspects of this problem. Summaries of the metabolic data in diabetic patients were made up in chart form and incorporated in an exhibit on diabetes mellitus at the annual

meeting of the Massachusetts Medical Society in Boston in May 1942. This same group of charts was used in a somewhat larger exhibit on diabetes mellitus which was presented at the meeting of the American Medical Association in Atlantic City, June 8 to 12. This exhibit and the lectures connected with it received a special certificate of merit from the judges of the scientific exhibit. The exhibit has been requested by the Medical Society of the State of Washington to form part of their scientific exhibit at their annual meeting in August at Spokane, Washington.

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CHARLES W. METZ and MARTHA LEE BOZEMAN, University of Pennsylvania, Philadelphia, Pennsylvania. *Chromosome studies on Sciara.* (For previous report see Year Book No. 40.)

Evolutionary chromosome changes in Sciara. The remarkable opportunities provided by the giant salivary-gland chromosomes of Diptera for studies on chromosome evolution have led to numerous investigations in recent years, notably on the genus *Drosophila*. Although far from complete, the studies of the various investigators on *Drosophila* have put the study of chromosome evolution in that genus on a new basis, much more accurate than was possible before, and have provided a large body of detailed information concerning

the changes occurring within the chromosomes during the course of evolution. In order to evaluate the broader significance of the findings in *Drosophila* it is necessary to determine whether or not they apply also to other groups of organisms. For this reason we have been making an intensive study of conditions in the genus *Sciara*, a group of fungus flies far removed taxonomically from *Drosophila*. These flies are especially favorable for the purpose, as was pointed out in earlier publications. In certain respects conditions in

Sciara apparently do not conform to the pattern established in *Drosophila*, and especial attention is being given to the points of difference. The major emphasis, in both genera, has been laid on morphological or quantitative chromosome changes. These involve rearrangement of parts (mainly inversion of pieces of various sizes within individual chromosomes) and loss or addition of parts. Rearrangements appear to be characteristic of *Drosophila*; they are found commonly within individual species and also are revealed by study of species hybrids. In *Sciara*, rearrangements apparently occur rarely in some species and more commonly in others. The reason for this difference is not yet evident. Rearrangements are to be expected in maximum numbers in species hybrids; yet careful comparative study of the organization of homologous chromosomes in hybrids between *Sciara ocellaris* and *S. reynoldsi* has revealed evidence of only two rearrangements (inversions), involving only one chromosome (unpublished observations of Dr. Pauline Rohm). In certain other species of *Sciara*, however, numerous rearrangements are found simply by examination of wild populations within the individual species, as was noted in last year's report.

Rearrangement of parts of chromosomes, unaccompanied by other changes, presumably can play only a very limited role in evolution. Additions of chromosome material, however, may provide the necessary basis for "progressive" evolutionary change in the germ plasm. As has been pointed out by Bridges, the "repeats" found in the salivary-gland chromosomes of *Drosophila* come in this latter category. They are relatively short regions which are present in duplicate within a chromosome. Presumably they have arisen by insertion within a chromosome of a small part of a sister or homologous chromosome. Such

"repeats" are found in small numbers in both *Drosophila* and *Sciara*. Especial interest attaches to the study of "repeats" in species hybrids, for such study gives an indication of how long chromosome material which is in duplicate, and therefore presumably not subject to the effects of natural selection in the same manner as other parts, can persist without modification. In *Sciara* a "triple repeat" is present in the X chromosome of each of the species mentioned above (*ocellaris* and *reynoldsi*). Although not yet complete in finer details, our study of this condition, including study of the hybrids between the two species, continues to indicate that the repeats are probably identical in the two species and hence that the condition has persisted without serious modification of the genetic material through the period of evolution of these species from a common ancestor.

In addition to rearrangements and "repeats," there are minute modifications which, in a descriptive sense at any rate, come in other categories. They appear to be rare in *Drosophila* and relatively common in *Sciara*. Some of them appear to involve the loss of single "bands" or disks, as seen in the giant chromosomes; they are designated "deficiencies." Others appear to represent a doubling of single disks or very short chromosome regions. They are referred to as "duplications" and presumably have much the same significance as "repeats," but their precise nature is not yet understood. For the latter reason, as well as because their mode of origin is unknown, these minute modifications are receiving especial study, particularly in the species hybrids mentioned above. Although this work has been extended during the past year, the results are not yet sufficiently clear-cut to warrant detailed discussion.

Artificially induced chromosome changes.

As was noted in earlier reports, the nature of the chromosome modifications in *Sciara*, and the relative frequencies of the different types as compared with those in *Drosophila*, make it important to get an understanding of the chromosome mechanisms responsible for the changes. The best approach to this problem seems to be through study of artificially induced chromosome modifications, using irradiation and other treatments. Such a study has been under way for some time and has received particular emphasis during the past year. The recent experiments are reviewed briefly below. In these experiments the treatment has been applied to the germ cells (mainly oöcytes) and the results have been observed by examining the salivary-gland chromosomes of the F_1 larvae.

Earlier work, reported last year, indicated that in the developing oöcytes of *Sciara ocellaris* the chromosomes are resistant to irradiation for a considerable period, judging by the absence of recoverable rearrangements following treatment. It also indicated that during the period in question the chromosomes undergo little, if any, movement, which suggested that perhaps absence of movement is here responsible for absence of rearrangements. In further investigation of the problem two lines of attack have been followed. One has involved an extension of the experiments and cytological observations to other periods of development in order to determine the exact limits of the "insensitive" period and to determine the morphological characteristics of the chromosomes at all stages in this period. The other has involved experiments designed to induce sensitivity to irradiation, or to induce rearrangements in the chromosomes, during the "insensitive" period. Such studies, if successful, ought to aid materially in revealing the nature of the chromosome mechanisms in question.

As a result of a large series of experiments, the limits of the "insensitive" period have now been defined with reasonable accuracy. In the present species the oöcyte chromosomes are "resistant" to irradiation with X rays, or gamma rays of radium, from about the beginning of the oöcyte growth period, during early larval life, until the second day after eclosion of the adult (approximately 15 days). By comparison with earlier cytological observations (Berry, 1941; Metz and Bozeman, 1940) it is seen that this period of resistance coincides with a period of prolonged "prophase" during which the synapsed chromosome pairs remain in condensed long threads evenly spaced about the periphery of the nucleus. Reynolds (1941) demonstrated that during the second day of adult life of the female the unlaidd eggs become sensitive to the effects of X rays, and that this sensitivity starts at about the time the oöcyte chromosomes begin to move onto the spindle.

Since one of the obvious changes associated with increased susceptibility to X rays is movement of the chromosomes, it was thought that rearrangements might be induced by combining artificially induced movement with irradiation. Experiments were carried out to test this possibility. Presumably movement alone does not produce aberrations, because spontaneous rearrangements are rare in *Sciara*; nevertheless the possibility was tested in some of the experiments.

At about 26 hours after eclosion, at 23° C., the first meiotic division begins, and it proceeds to first anaphase by about 29 hours. The two groups of chromosomes are then well separated and remain in this condition until the eggs are laid, about 24 hours later.

It was found that the chromosomes of the larval oöcyte nuclei could readily be displaced by centrifugation. A force of

about $1700 \times$ gravity applied for 1 hour will move the chromosomes into a small space at the centrifugal end of the nucleus. In this condition individual chromosome threads cannot be distinguished and the chromatin appears to be a mass occupying about one-tenth of the volume of the nucleus. No rearrangements were found in 72 slides from centrifuged material.

On the assumption that induced movement combined with radiation might be effective in bringing modified chromosome regions or broken ends into proximity and hence provide opportunity for rearrangement to occur, larvae were centrifuged before and after irradiation. The cytological stage of every group of experimental animals was determined by examination of ovarian smears of sister flies made at a time as nearly as possible coincident with the time of treatment. In the first such experiment, using dosages of $1700 \times$ gravity and 2 gram-hours exposure to radon, the fertility was very low and only 12 preparations were obtained. No rearrangements were found in these. In a second experiment an X-ray dosage of 1980 r units and a centrifugal force of about $5000 \times$ gravity were used. From material irradiated after centrifuging, the counts were as follows: 26 unaffected, 2 probably unaffected, and 4 unfavorable for study; from material irradiated before centrifuging: 60 unaffected, 8 probably unaffected, and 11 unfavorable.

Though no rearrangements were detected after centrifuging and irradiating in close sequence, it seemed possible that the effect of the radiation was delayed and that rearrangements might occur if the chromosomes were brought into proximity at some hours after irradiation. To test this possibility, five experiments were carried out. A dosage of $5000 \times$ gravity and of 3000 r units was used in each case. The results may be summarized as fol-

lows: (1) Centrifugation $\frac{1}{2}$ hour before irradiation, 8 specimens, no rearrangements; (2) centrifugation $\frac{1}{2}$ hour after irradiation, 28 unaffected, 1 rearrangement (small deletion); (3) centrifugation $1\frac{1}{2}$ hours after irradiation, 22 unaffected; (4) centrifugation 4 hours after irradiation, 25 unaffected, 1 rearrangement (reversed repeat); (5) centrifugation 20 hours after irradiation, 30 unaffected.

The number of rearrangements found in this experiment is too small to permit the conclusion that they were induced by the combined treatment. They may have been induced by the irradiation alone or possibly have been spontaneous.

Chromosome movement was also induced by immersing larvae in paraffin oil, which causes partial asphyxiation and irregular clumping of oöcyte chromosomes, but no rearrangements were induced by this treatment (18 specimens). Larvae were asphyxiated and then irradiated in an attempt to induce rearrangements. An X-ray dosage of 5000 r killed all the asphyxiated larvae and 17 of the 22 unasphyxiated controls. The survivors were sterile. Two adults emerged after asphyxiation followed by irradiation with 2530 r units, and no rearrangements were found (51 specimens).

The work just described was all done on larvae in which the chromosomes were condensed and distributed about the periphery of the nucleus. The dosages used were approximately 2000 to 3000 r. A total of 435 F_1 larvae examined showed only 2 rearrangements. The same general cytological condition persists through the pupal stage and the first day of adult life. In considering later stages, especial interest attaches to the correlation between the mitotic activities of the chromosomes and susceptibility to X rays. Prepupae and pupae irradiated with a dosage of 4 gram-hours of radon showed 351 unaffected and

1 rearrangement. Earlier work of Metz and Boche (1939) indicated that during the first day of adult life females were resistant to irradiation, and this observation was supported by further work in which, using females irradiated at less than 30 hours after eclosion, there were no rearrangements in 56 specimens. Reynolds (1941) extended the period of irradiation into the second day of adult life. Rearrangements were induced at 28 hours after eclosion, when the chromosomes were "late prophase tetrads," and susceptibility was found to increase as meiosis progressed to metaphase. We have repeated this work, with controlled temperature of 22–23° C., using a dosage of about 1100 r. Control smears showed that metaphase of the first meiotic division is reached at about 26 hours. There is some variability in stage in any one ovary, and presumably more between individuals of the same age.

Irradiation of adults younger than 22 hours (prophase) produced no rearrangements (6 specimens). Irradiation of adults 22–24 hours old (beginning of prophase movement) produced aberrations in 4 specimens (14 per cent affected). Irradiation of adults 25–26 hours old (metaphase) produced aberrations in 9 specimens (19 per cent affected). Irradiation of adults 27–31 hours old (anaphase) produced aberrations in 18 specimens (25 per cent affected). Irradiation of adults 54–55 hours old (anaphase) produced aberrations in 10 specimens (50 per cent affected). These results indicate that the incidence of susceptibility coincides with the beginning of meiotic movement, and increases throughout the meiotic period. Further experiments are being carried out to determine more exactly the correlation of these phenomena.

A period of mitotic activity precedes the growth period of the oöcytes, and larvae were treated during these gonial divisions to determine whether chromosomes at this

period were also susceptible to irradiation. Age is measured from the day the adults were mated. Hatching occurs at about 7–8 days. A dosage of 1000 r was used. Irradiation of larvae 13 days old produced 2 rearrangements, with 1 unaffected; irradiation of larvae 14 days old produced 10 rearrangements, with 88 unaffected; irradiation of larvae 15 days old produced 3 rearrangements, with 32 unaffected. A higher dosage (2500 r) was used on older larvae, and no rearrangements were induced in larvae 20 days old (101 specimens); 2 aberrations were induced in larvae 21 days old (47 unaffected). The larvae used for combinations of irradiation and centrifugation were 25–29 days old, and 2 aberrations were induced (435 specimens). The highest percentage of rearrangements occurred in 13-day larvae, but the number of flies is too small to permit the conclusion that this stage is most susceptible. The period of sensitivity ends with the onset of differentiation, and almost no rearrangements can be induced after the chromosomes become condensed into prophase threads.

Although not demonstrative, evidence obtained in these recent experiments suggests that a correlation exists between the types of chromosome rearrangement secured and the stage of mitosis (or meiosis) at which the treatment is applied. Early in the study of the aberrations induced in young larvae, a chromosome configuration never before reported in *Sciara* was detected. This was a duplication of a segment of chromosome, usually added so as to form a "direct repeat" with no intervening material. Three duplications formed reversed repeats similar to that described by Kaufmann and Bate (1938) in *Drosophila*. In all these duplications intimate synapsis occurs among all three homologous segments. Larvae irradiated during the gonial mitoses probably have all

mitotic stages present. Among 16 aberrations from such material there were 7 repeats, 4 inversions, 2 translocations, and 3 deletions. In larvae irradiated at 21 days (arrested prophase), 1 inversion and 1 reversed repeat were found. In later larvae in the same cytological stage, 1 deletion was induced in a female, 1 reversed repeat in a female or male, and 1 direct repeat in a male. The only aberration found in offspring of irradiated pupae was a translocation, but this may have been induced in a male.

By the irradiation of adults 22–24 hours old, in which the oöcytes are in prophase of the first meiotic division, only direct repeats were induced. By irradiation of adults 25–26 hours old, in which the oöcytes are mainly in metaphase but also show some prophase and anaphase figures, 4 direct repeats, 1 inversion, 3 deletions, and 1 repeat of a section at some distance

were caused. By irradiation of adults 27–31 hours old, in which the oöcytes are mostly in anaphase, 6 direct repeats, 22 inversions, no deletions, 1 translocation, 3 transpositions of segments, and 3 duplications of segments at some distance were induced. By irradiation of adults 54–55 hours old, 7 repeats, 8 inversions, and 2 deletions were induced.

The lowest percentage of direct repeats is obtained from flies irradiated in the period from 27 to 31 hours (when the oöcytes are in early anaphase), and the highest percentage of repeats occurred in flies irradiated in the period from 22 to 24 hours (when the oöcytes are in prophase).

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T. H. MORGAN and JACK SCHULTZ, California Institute of Technology, Pasadena, California. *Investigations on the constitution of the germinal material in relation to heredity*. (For previous reports see Year Books Nos. 15 to 40.)

The report by Dr. Jack Schultz which follows is based on the work of the period ending January 1942. In last year's report there was discussion of several series of experiments designed for a study of the functional differentiation of the chromosomes. The convergent genetic, cytological, and cytochemical studies have been pursued.

The study of the function of heterochromatin by means of the analysis of the variegated types of *Drosophila* has been continued. The distribution of heterochromatin in the chromosomes has been studied, by the analysis of the modifiers of the grade of variegation. Since the grade of variegation depends, other things being equal, on the heterochromatin balance of the nucleus, it was reasoned that the de-

termination of the loci of a series of modifiers of variegation would permit the detection by genetic means of possible "interstitial" heterochromatin, in addition to the centromeric heterochromatin already studied. The experiments on the localization of these types have been continued, but are not yet ready for complete report. Accumulation of analyses of the many individual cases continues, and the statement of last year's report that the majority of the modifiers are themselves rearrangements affecting centromeric heterochromatin has received supporting evidence from new cases; in addition, some new instances have been observed of modifiers located in the more distal regions, presumably in the so-called "interstitial" heterochromatin.

The detailed analysis of the function of the heterochromatin of the second chromosome led, as was reported last year, to the discovery of a differentiation between the heterochromatin of *Drosophila melanogaster* and that of the closely related species *D. simulans*. It will be recalled that it was possible to show that striking abnormalities in the growth and differentiation of the organs of the hybrids were induced by a deficiency of the heterochromatin in the right limb of the second chromosome. Continued analysis has shown that the melanotic necrosis ("tumors") of the fat bodies (one of the characteristics in these crosses) may occur without the appearance of the duplicated organs, and that it is apparently specifically related to the rolled mutant. The previous work had shown that the hybrid males with a *simulans* X chromosome showed the "tumors" but not the duplicated organs. A new type of female hybrid, containing two *simulans* X chromosomes, from the progeny of mating attached-X *simulans* females to *melanogaster* males, displays, as the males did, only the "tumors," and no duplicated organs. The conclusion is therefore confirmed that the X-autosome relation, and not the sex of the hybrids per se, determines whether duplicated organs occur. Nevertheless, there is a relation between the melanotic "tumors" and the duplicated organs: the duplicated organs in these crosses have not been observed except in individuals containing "tumors" as well. The relation still remains to be worked out, since different strains of *simulans* differ in their behavior in this respect.

The question of the possible relation of these effects in the hybrid to the effects on variegation of the *melanogaster* deficiency Minute S10 has been studied. Experiments on the variation of the heterochromatin balance in relation to the effects of the deficiency have been carried out. The

Minute in question is a slight type, which, when heterozygous for the mutant rolled, permits the variable manifestation of the rolled effects in a form not quite so extreme as the other deficiencies for the rolled locus. It was found that the Minute S10 effects themselves show some variation with heterochromatin balance within the species *melanogaster*: the XO males show spread wings and their bristles appear coarser than those of the XY males, with some supporting but not conclusive evidence that the addition of Y chromosomes further intensifies the Minute effect. It is already known that in the variegational chromosome rearrangements between heterochromatic and euchromatic segments, addition of heterochromatin to the nucleus causes the heterochromatic genes brought near the euchromatin in the rearrangements to display the phenotype of the recessive mutants known at the loci in question. Thus the "light" locus is in heterochromatin, and in rearrangements where it is transferred to euchromatin, the phenotype of the heterozygote for light and the translocation is wild type in the XO male, light in the male with three Y chromosomes. Similarly in the present deficiency for the heterochromatin block, if the rolled locus were present, but undergoing a modification of function due to its position closer to euchromatin, it would be expected that addition of Y chromosomes to the genotype would increase the intensity of the rolled effect. Experiments to test this possibility have so far shown that this is not the case, and that the manifestation of rolled is the same in both XX and XXY individuals. There are, however, lethal effects, and a certain half-thorax type appearing in the deficiency-rolled heterozygotes, which are not yet explained. It is evident, however, that the simple postulate of an interaction in

the hybrid between a modified heterochromatin balance and a variegational translocation is not sufficient to account for the situation.

Last year the discovery was made that the heterochromatic regions divide more slowly in the endomitotic divisions of the nurse cells than do the euchromatic regions. Further evidence has been obtained from the study of the nurse-cell divisions in other species of *Drosophila* (*virilis*, *robusta*, *simulans*, *pseudoobscura*) that the picture is consistent within the genus. A preliminary study of *Calliphora viridescens*, however, shows a slighter difference between the rates of division of the euchromatin and the heterochromatin of the nurse cells. This finding is of interest in connection with the work of Geitler on the behavior of heterochromatin in the endomitotic divisions of the Hemiptera, in which he considered the number of heterochromatic masses in the nucleus as an index of the number of endomitotic cycles, and found a rough correlation with the nuclear volumes. This offers a striking contrast to the picture of unequal rates of division in the *Drosophilas*. The situation in *Calliphora* is apparently intermediate between that in the *Drosophilas* and that in the Hemiptera studied by Geitler. It seems not unlikely that in different species, and perhaps within the species among the different tissues, the variation of rates of endomitotic division for the different parts of the chromosomes (or the genes themselves) may be characteristic for each type of cell.

The cytochemical analysis of the chromosomes by the combined use of staining technique and enzymatic digestion has been continued. The present series of experiments had as their object a survey of the differential resistance to digestion by the enzyme ribonuclease of nuclei at dif-

ferent stages of mitosis, or of differing structural types. It will be recalled that the results of last year cast doubt on the reputed specificity of this enzyme for ribonucleic acid, unless it were assumed that the structural framework of the chromosomes of the salivary gland is a ribonucleic acid. In the present study, covering *Narcissus* root tips, grasshopper and salamander testes, and sperm of *Chaetopterus*, *Chiton*, *Ciona*, *Cynthia*, *Lytechinus*, *Megathura*, and *Patiria*, as well as the eggs of some of these types, evidence of the same sort was obtained. Metaphase chromosomes, the bands of the salivary-gland chromosomes, and highly condensed sperm heads such as those of *Chiton* and *Drosophila* proved most highly resistant. The most sensitive structures were those of the "resting nuclei." In the cytoplasm of the eggs examined, it appeared that some of the protein (staining with the fast green stain) was digested away, showing that other substances in addition to the ribonucleic acids of cytoplasm are affected by the enzyme. From these results it follows that during those stages of the nuclear cycle when the concentration of protein is high, either ribonucleic acid is present in the chromosomes, or (in agreement with data of Dr. Mazia) a protein fibrous structure in the nucleus is digested by the enzyme. The cytochemical data are at present consistent with either hypothesis, since the apparent correlation of ribonucleoproteins with the processes of protein synthesis calls for their presence in the resting nuclei, and not in the metaphase, where synthesis is presumably at a minimum.

There is a further agreement to be noted between these results and the recent application to mitosis, by Caspersson, of the Miescher-Kossel hypothesis of a change in the protein constituents of the nucleus.

According to this view, the complex proteins of the nucleus are broken down during the prophase, and the proteins remaining are nucleohistones or protamines.

H. C. SHERMAN, Columbia University, New York, N. Y. *Research on influence of nutrition upon the chemical composition of the normal body.* (For previous reports on this and directly preceding researches, see Year Books Nos. 32 to 40.)

From the starting point of an experimental dietary which, like many present-day human food supplies, was adequate for the perpetuation of the population in passable health, but suboptimal, as shown by its nutritional improvement under controlled conditions, the chiefly significant enrichments appeared to be those of calcium and riboflavin content and of vitamin A value. The constructive character of the findings with these three chemical factors gave rise to a new research to determine how far the favorable effects of these increased nutritional intakes can be explained by increased concentrations of these nutrients in the essential substance of the body. By analytical methods, whether of the classic type with modern improvements, or physicochemical, or biochemical, we seek to ascertain just what degrees of normal flexibility actually exist in the traditionally alleged *fixité* of the body's internal chemistry. The experiments with diets of different calcium content were completed in 1941. The corresponding experiments with different levels of nutritional intake of riboflavin and of vitamin A have been and are being continued, but in each case the rate of progress has been slowed down by war conditions, research assistants having resigned to take up work on more directly military problems. The nutritional problems here under consideration, however, undoubtedly have such significance for the maintenance and upbuilding of human

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health and efficiency that the fact of our being at war accentuates the importance of completing this research.

In the experiments of the past year, a doubling of the riboflavin content of the food, within the range which supports the "plateau of optimal performance," has appeared to induce a slightly higher concentration of riboflavin in the liver, which difference increases with physical maturity; and a probably insignificantly higher concentration in the muscles, whose riboflavin content seems to diminish with increasing age. The cases thus far studied are too few to permit a definite conclusion as to the significance of these small differences in the analytical findings.

Satisfactory completion of these riboflavin studies will require extension of the experiments to larger numbers of cases and through a wider range of age, with attention not only to the level of nutritional intake of riboflavin itself, but also to that of phosphate and protein. The latter point particularly needs investigation because it is now known that riboflavin functions importantly in the tissues in combination with phosphate and protein.

In the studies of the effects of enrichment of dietaries with vitamin A, the work of the past year indicates the importance of the higher intakes for the maintenance of full bodily reserves and optimal nutritional well-being with increasing age, even from earliest adulthood. Hence this part of the research also carries human implica-

tions to which the war gives accentuated significance.

Both the riboflavin and the vitamin A experiments will therefore be continued to the extent that the existing opportunity permits.

The generous and efficient service of those who have collaborated in the work

here reported, whether as research assistants or as volunteers, is gratefully acknowledged.

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DIVISION OF HISTORICAL RESEARCH

Cambridge, Massachusetts

A. V. KIDDER, *Chairman*

Well before the entry of the United States into the war it had become evident that the general financial situation along with the rapidly expanding defense activities of the Institution would sooner or later necessitate curtailment or deferment of customary and normal research programs. The Division's 1941-1942 program was accordingly formulated with a view to gathering as great an amount of raw data as possible in order that members of the staff not in war service might be able profitably to pursue their studies, for a relatively extended period, with a minimum of expense for field work. The season therefore opened earlier than usual, and when hostilities broke out, several parties were already in Central America and others were on the point of departure. Inquiry as to further procedure brought instructions from the Institution headquarters that original plans should be followed; and, later, the United States legations in the countries concerned requested that undertakings having value in supplementing the Government's program of inter-American cultural relations be continued. All scheduled explorations and excavations could thus be carried to completion. When the Axis submarine campaign was extended to the Gulf of Mexico and the Caribbean, however, it was decided that irreplaceable specimens and notes should not be exposed to the risks of ocean transportation. Hence Messrs. R. E. and A. L. Smith, Strómsvik, Shook, Ruppert, and Richardson are remaining in Central America to work up their materials.

An unusually large number of excavations were undertaken. In Yucatan, Dr.

Morley cleared the elaborately decorated façade of a buried temple at Uxmal; Messrs. Brainerd and Andrews worked at Mayapan, Acanceh, and other ruins in the northern part of the peninsula, gathering ceramic and architectural data which will be of much value in interpreting the later prehistory of that region. In Guatemala, the investigation of the great archaeological site of Kaminaljuyu in the outskirts of Guatemala City was continued. Mr. Shook completely excavated a large mound, which proved to contain a superposition of four structures, and three tombs, one of them the richest in pottery and jades so far found at Kaminaljuyu. Mr. A. L. Smith worked on three of the several rectangular courts in which the ancient ceremonial ball game was played. These yielded a number of fine stone sculptures, mostly serpent and parrot heads with human faces in their open mouths. The Chairman devoted the season to preliminary study of the great amounts of pottery recovered by Messrs. Shook and Smith.

In Honduras, Mr. Strómsvik carried into its eighth year the program of excavation and preservation of the ruins of Copan, sponsored jointly by the Government of Honduras and Carnegie Institution. He completed the repair of Temple 11, now known, because of the long hieroglyphic texts adorning its walls, as the Temple of the Inscriptions. He also discovered south of the Acropolis an area containing numerous graves. As these held a great many mortuary vessels, representing several periods, his collections will throw much light on the local sequence of pottery types.

The excavations at San Andres, El Sal-

vador, directed by Mr. John Dimick were not pursued this year because of Mr. Dimick's entry into war service, but his assistant, Mr. S. H. Boggs, remained in Salvador to make a photographic record of the many large private collections of archaeological specimens in that country. Correlated with the Division's program was a survey of eastern Salvador by Mr. John M. Longyear, of the Peabody Museum of Harvard University, a project carried out under the auspices of the Institute of Andean Research with funds provided by the Coordinator of Inter-American Affairs. The Chairman served as director and visited Mr. Longyear several times in the field. The latter made a reconnaissance of the country east of the Lempa River, locating and mapping a large number of sites. He also excavated a small ruin at Los Llanitos, south of San Miguel, which proved to contain an interesting ball court, the southernmost yet recorded. Mr. Longyear's report will be issued by the Peabody Museum.

In Nicaragua, Messrs. F. B. Richardson and Karl Ruppert continued the investigation at El Cauce, near Managua, where in 1941 Mr. Richardson discovered human footprints in a deeply buried layer of consolidated volcanic mud (Year Book No. 40, pp. 300-302). The footprints were followed for several meters farther and a protective structure was erected over them. Mr. Ruppert devoted the season to study of archaeological remains in the recent deposits overlying the volcanic strata. Final judgment as to the antiquity of the footprints must await the working-up of Mr. Ruppert's materials, further research on the volcanology of the region, and paleontological studies bearing on the age of cer-

tain animal tracks found by Mr. Richardson.

No field work in ethnology or linguistics was undertaken, as Drs. Redfield and Tax and Messrs. Villa and Rosales were engaged in preparing reports on earlier investigations. Dr. Abraham M. Halpern joined the staff in 1941 to continue the study of Maya languages which was interrupted by the death of Dr. Andrade. Dr. Halpern, however, has been granted leave of absence for war service.

Researches in the history of science and in documentary history have gone forward, Drs. Sarton and Pogo working in Cambridge, Dr. Stock in Washington, and Mr. Scholes and Miss Adams in Albuquerque, where Mr. Scholes also conducted a course in methods of archive study at the University of New Mexico. Dr. Chamberlain is on leave of absence, acting as Senior Cultural Assistant in the United States Legation at Guatemala City.

During the year the Division lost, through resignation, the services of Dr. Oliver G. Ricketson, Jr., a valued member of the staff since 1922. Dr. Ricketson accompanied Dr. Morley on several journeys of exploration in the Peten; he was in charge of the initial excavations in the Northeast Colonnade and the Caracol at Chichen Itza; he investigated the ruins of Baking Pot, British Honduras; he inaugurated and for several years directed the extremely important excavations at Uaxactun in the heart of the Peten jungle. To Dr. Ricketson's ability as an organizer and leader of expeditions into difficult country, and to his skill as a field archaeologist, is due a very large share of our present knowledge of the Maya Old Empire.

ARCHAEOLOGY

HONDURAS

G. STRÓMSVIK

As in former years, the activities of the Copan expedition, a project sponsored jointly by the Government of Honduras and Carnegie Institution, comprised both repair of buildings and excavations with purely archaeological objectives. Mr. Strómsvik was again in charge, assisted by Mr. Douglas Elliott and Sr. Jesus Nuñez, the latter completing the Spanish catalogue of the large collection now housed in the Copan museum.

The work of preservation was concentrated on the Temple of the Inscriptions (Temple 11), which in its day was perhaps the most imposing of the many elaborately adorned buildings of the Acropolis, as it dominated both the Court of the Hieroglyphic Stairway and the West Court. In previous seasons much repair had been carried out on the temple proper, and the great range of steps mounting to it from the Court of the Hieroglyphic Stairway had been cleared of debris and its upper parts consolidated. Much remained to be done, however, on the other side, where the stairway rising from the West Court to the first platform and that from the platform to the temple were badly broken down. Also, the seven terraces flanking the stairways had been so badly warped and the masonry so skewed by the enormous weight above them that it was deemed advisable to take them down stone by stone and rebuild them. As has always been Mr. Strómsvik's practice in such work, the areas to be dismantled were carefully surveyed and photographed, and each stone numbered before removal. Study of the plans and sections made clear certain previously unknown features of construction, and there

came to light, during the removal of fallen material, a number of fine sculptures fallen from the western and southern façades of the temple. In addition to the resetting of the western stairways and terraces, the south side of the temple substructure, the east half of the south stairway, and the southwest corner of the temple were rebuilt.

In former years the East Court had been entirely cleared, save for a great pile of fallen masonry in the northeast corner. This pile not only detracted from the appearance of the court, but offered the only hope of recovering sculpture from Temple 20, the greater part of which had gradually been eaten away as the Copan River, before its diversion, cut into the Acropolis. The heaped debris was cleared away, the excavation bringing to light materials which proved that the entire west façade of the temple had fallen forward onto its frontal stairway. From the heap came several hundred pieces of carved stone, among them some of the finest yet found at Copan: geometric elements, grotesque animal and human forms, dozens of Ahau faces of various sizes, and many finely sculptured human heads, from half natural size to as much as 0.75 m. high. These showed such great individuality as to suggest that they were portrait studies. There were also recovered more fragments of the large bat figures found earlier at the edge of this heap. It is thought that the bats were roof ornaments, standing free atop the west façade. Most of the above-mentioned sculpture is now arranged in rows along the steps of Temple 20; certain outstanding pieces have been moved to the museum.

Another phase of preservation work was the solidification of the tunnel under the Temple of the Inscriptions, about 30 m.

of which were lined with lateral masonry walls and roofed with a corbeled vault, to guard against possible cave-ins and leave the tunnel open for inspection by students and visitors who may wish to see the many interesting superimposed constructions that went into the building of the Acropolis. Minor tasks were the repair of a large jaguar sculpture, on Platform 20, which now lacks only the head and the feet on the left side; and the setting upon a solid base of the gigantic head at the northeast corner of the Temple of the Inscriptions.

The more strictly archaeological work of the season was largely confined to digging in search of burials and stratified rubbish deposits in the vicinity of the Acropolis. During the rainy season of 1941 two burials had been washed out of the riverbank 200 m. south of the Acropolis. Following this lead, a trench was run west from the bank, revealing an extensive and long-used cemetery. In the excavation of no more than 150 cu. m. of earth 25 burials were found, from close to the surface to a depth of over 3 m. Three distinct strata were recognizable: the uppermost assignable to the late or Great Acropolis period; the middle to the first or Early Acropolis period; the lowest, in which hardly any cut stone was found, to the pre-Acropolis period. Although most of the burials contained no mortuary offerings, some were provided with pottery vessels and jade, shell, and clay ornaments. About 50 pieces of pottery, whole or repairable, were recovered. Most of the skeletons were so rotted that only the teeth could be preserved. A number of these were inlaid with jade. Burials of the three periods may be characterized as follows:

Late or Great Acropolis period: Bodies usually placed flexed in rectangular masonry cists of well squared stones. Inlaid teeth common. Great variety of pot-

tery types, shapes, and colors; polychrome abundant; Copan adaptation of Usulután ware rare. Yajoa ware appears. Great quantities of the small, crude votive vessels usually called *candeleros*. Tentative dates for this period: 9.10.0.0.0 to 10.0.0.0.0 in the Maya time count.

First or Early Acropolis period: Bodies laid flexed in open ground, occasionally in burial cists of cut stones. Inlaid teeth present. Polychrome and "Copan red" pottery appear; many basal-flanged bowls; Copan adaptation of Usulután style common, incised black ware common, carved slab-legged cylinders with lids, many *candeleros*. Tentative dates: 8.15.0.0.0 to 9.10.0.0.0.

Pre-Acropolis period: Three skeletons found, all extended; two in crude oval burial cists of uncut stones and river boulders, roofed with large unshaped slabs. Length of skeletons as they lay in the ground: 1.61, 1.62, and 1.63 m. No inlaid teeth. Pottery: red-on-buff, ring-base bowls with red rim, true Usulután plates with large bulbous legs, red-on-cream effigy jugs, carved slab-legged cylinders with lids, many *candeleros*. Tentative dates: ? to 8.15.0.0.0.

Metates without legs and with tapering handstones were common in all three strata, as were clay griddles.

During the season the museum catalogue was greatly amplified; many fine sculptures were repaired and placed on exhibit; and five new showcases were installed, containing pottery, ornaments, and skeletal material, among which is a complete skull with inlaid teeth, of the Early Acropolis period.

YUCATAN: UXMAL

S. G. MORLEY

Dr. Morley returned to Yucatan by way of Mexico City in September 1941. While

in Mexico City he delivered a lecture at the University Club, for the benefit of British war relief, on the archaeological investigations of the Institution during the past 25 years, and repeated the lecture in Spanish before the Sociedad Científica de Antonio Alzate.

During Dr. Morley's field work at Uxmal in the early part of 1941, a preliminary examination of the Great South Pyramid, a high, tree-covered mound southwest of the House of the Governor, revealed a section of a collapsed corbeled vault on the north or front side. This confirmed an impression, formed many years ago, that near the summit of this pyramid there had originally been ranges of rooms on each of the four sides. Dr. Morley devoted three weeks to excavations on all four sides of the pyramid, near the top, in order to establish the nature of the construction that had stood there.

The Great South Pyramid, the highest and largest at Uxmal, measures 96 m. north and south by 80 m. east and west, and is 27.5 m. high from the north base to the summit. It is built on a slope which rises from north to south, so that its base at the south is 4 m. higher than at the front. Two definite architectural periods were noted, and it is quite possible that the pyramid may contain still older constructions. The earliest building now visible consisted of a single range of at least four rooms, with long axes running east and west and doorways in their north walls. These were later incorporated into the northwest corner of the pyramid, their exterior back walls being covered by its masonry fill.

The pyramid proper was of eleven terraces, ten at the back because of the southward rise of the terrain. The terraces, 1.42 m. in vertical height, have battered faces. They are built of very roughly dressed stone like that of the substructure of the House of the Dwarf, and were finished

with a heavy coat of lime plaster. There were no recessed panels or other decoration on the faces of these terraces. A centrally placed stairway on the north side, 23.5 m. wide, projecting from the base of the pyramid and having about 70 steps, gave access to the uppermost terrace, which was also reached from the back by a somewhat narrower stairway, asymmetrically placed and in two offset flights.

On the highest terrace is a platform, 1.32 m. high, all four faces of which are decorated with an elaborate sculptured mosaic, the principal elements being the lattice pattern and the familiar Maya grecque. The platform is ascended by relatively narrow stairways of five steps each, at the north and south. On the platform, and built around and against a solid central core on the top of the pyramid, are four ranges of rooms; that on the front or north side seems originally to have consisted of five nonconnecting vaulted chambers entered by doorways in their north walls. The east, south, and west ranges, however, were almost entirely solid, there being only a single vaulted room at the middle of each; the long ends of all three, so far as could be determined, were of solid masonry. These four ranges of rooms are 6 m. high.

At some later time, a second outer tier of three vaulted rooms had been built in front of the three middle rooms of the north range. When these were added, the floor level of the old middle room was raised 1 m. above the floor level of the new chamber in front of it. The 1 m. from the floor of the outer middle room to the sill of the doorway of the inner room was sculptured with a magnificent Maya mask 3.25 m. wide and 1 m. high, which is in a perfect state of preservation. Indeed, it seems probable that the level of the inner middle room was raised expressly to provide a surface for the presentation of this

panel, which closely resembles the mask panel in an identical position in the middle outer room of the palace at Kabah.

The solid central core of the pyramid, surrounded by these four ranges, rises another 1.70 m. above the level of their respective roofs. There seems never to have been any construction on its summit, nor any stairway ascending to it from the level of the sculptured terrace which supported the rooms.

As a second major constructional undertaking, the pyramid was covered from bottom to top with a layer of rubble 1.5 m. thick, much of it composed of dry-laid, large, irregularly shaped pieces of limestone. The surface of this rough covering, completely enclosing not only the stucco-faced, terraced pyramid and sculptured upper terrace but also the elaborately ornamented façades of the four ranges of rooms, would also seem to have been terraced, though these later terraces are much broken down.

A possible reason for the encasement of the pyramid and its superstructure may have been that the sculptured façades of the four ranges of chambers had begun, soon after they were built, to fail, to crack and bulge outward so seriously that it became necessary, in order to keep the whole upper part of the pyramid from crashing down, to give it the support of added masonry, especially at the top where it could sustain the falling façades and prevent them from pushing outward. Incidentally to these operations, the ranges of rooms were filled solidly with dry-laid rough rubble, and the entire construction was converted into a great new pyramid, the main stairways on its north and south sides still being retained. It is probable that eventually this larger pyramid would have served as substructure for some sort of building had not final collapse of the Maya in the thirteenth and fourteenth cen-

turies halted this grandiose project before its crowning structure could be erected.

Owing to the burial of the elaborately sculptured façades of the building near the top before they had been exposed to much weathering, the façades were in practically perfect preservation. The north façade bears an intricate mosaic in both the upper and lower zones, in which panels decorated with geometric designs, grecques, and so forth appear. On the east, south, and west the upper zones only are decorated, the lower zones being of plain dressed stone.

Such is the beauty of the mosaic, the grace of the proportions, the size and commanding height of this pyramid, that it must, in its day, have been the most arresting building in the city.

As nothing like complete excavation could be attempted in the time available, only such trenches were dug, on the four sides and at the four corners near the top, as would permit the making of ground plans and elevations. The style of architecture indicates that the building was erected at the very height of the Puuc period, perhaps during the twelfth or thirteenth century. Some associated ceramic material was found, and two human skeletons, the bones and crania gone to powder.

In addition to the work on the Great South Pyramid, the Northwest Group was entirely bushed, and a map and north-south cross section were made. This group has some of the earliest masonry found at Uxmal; the flat building stones are only very roughly dressed, and in some cases extend clear through the walls; both exterior and interior surfaces undoubtedly were plastered.

Dr. Morley left Yucatan April 8, 1942. He delivered the Benjamin Franklin Medal Lecture before the American Philosophical Society at Philadelphia April 23,

and is spending the summer at Santa Fe, New Mexico, where he has had summer offices at the Laboratory of Anthropology for many years.

YUCATAN: POTTERY

G. W. BRAINERD

The present study of Yucatecan ceramics was begun in December 1939. The year 1940 was spent in Yucatan in the classification, tabulation, and illustration of the extensive sherd collections gathered during the previous work of the Institution (Year Book No. 39, pp. 270-274); 1941 in Cambridge in making chronological studies from previous notes, in comparative work on museum and published material, and in preparation of the material for publication.

The analysis of the pottery collections showed that an overwhelming percentage of these belong to two major periods, neither of which can be accurately dated in either the Christian or the Maya calendar, and which together represent the relatively short part of the span of human occupation in the Yucatan Peninsula characterized by the building of the more imposing of the standing architecture. The two major periods represented in the material excavated previous to this study can be identified with (1) the major buildings in ruins of the so-called Puuc region—Sayil, Labna, Kabah, and Uxmal—and the earlier buildings at Chichen Itza; and (2) the later, or "Mexican," buildings at Chichen Itza. These periods will be called "Puuc" and "Mexican" respectively for ease of reference. In addition to these main groups, pottery referable to all the Peten periods was represented in various collections but without definite stratigraphic association with the native pottery. At Chichen Itza there were stratigraphic evidences of a later ceramic period, the pot-

tery of which equates with isolated fragments and specimens from widely separated localities in Yucatan. A considerable number of distinctive groups of fragments occur in collections which could not be placed chronologically from the collections on hand last year. The collections made from Oxkintok in 1940 produced a large sample of pottery stratigraphically proved to antedate the Puuc period and inferentially associated with the earlier style of Oxkintok architecture (E. M. Shook, *Revista mexicana de estudios antropológicos*, vol. 4, no. 3), in which a lintel dated 9.2.0.0.0 was found.

This year's program was planned to supplement the available material to such an extent that a general chronological sequence, including the total span of pottery making on the peninsula, could be built up and its major periods described. It was also hoped that the completion of such a span would allow it to be dated with regard to the Maya calendar, the Christian calendar, or both, thus furnishing material to aid in the correlation of the two calendars.

The field work during the present season has consisted of five trips which together occupied approximately three months. Each group of ruins investigated was sampled by ten to twenty trenches distributed throughout the site. From one to five of these were usually found to contain large stratified deposits, the analysis of which served as the key by which the other collections from the site could be identified. The best sources of large, stratified deposits proved to be cenotes whenever these were present near the ruin. Since the end of the field trips the greater part of the collections has been classified and tabulated, and illustrations have been prepared for about half the material. Mr. R. E. Smith spent several days

in Merida in the examination of this year's collections, making available to the study his thorough knowledge of Peten pottery typology. The tentative results thus far obtained will here be presented in the order of excavation.

Yaxuna was visited. A previous sample excavated from this site, though small, shows a large variety of pottery types and considerable Peten contact. The larger collections obtained on this trip permit the definition of four distinct periods, characterized by changes in the basic wares. The first period can be equated definitely with the pre-Old Empire period in the Peten. The second seems to equate with early Tzakol in the Uaxactun chronology, but stylistically shows closer similarities to Early Ticoman pottery of the Mexican highlands. The third period appears to have been contemporaneous with later Tzakol and Tepeu I at Uaxactun. The last period equates with the pottery of the Puuc, or the earlier great building period at Chichen. A sculptured stela and a sculptured jamb were found and notes, drawings, and photographs made. Additional mapping was done on the site. Work of this sort was conducted at each site visited, including sufficient mapping to locate all pottery trenches accurately.

The site of Dzibilchaltun has not previously been reported upon. It lies 1 km. south of the hacienda of the same name, and about 15 km. north of Merida. It consists of an aguada with a near-by ruined colonial church standing in the center of a Maya plaza. The site was suggested by Professor Alfredo Barrera Vasquez as a likely source of early colonial pottery. In addition to such pottery, several large groups of ruins, two partially standing Maya buildings, about 2 km. of causeways, and 22 stelae (6 of which were sculptured) were discovered and mapped.

Measured drawings were made of the Spanish buildings and of remains of frescoes in the church. At one of the buildings a dubious sculptured date of 1593 was found, which, however, is given some support by a date of 1617 discovered at the architecturally similar church of the neighboring village of Chablekal. Mr. E. W. Andrews took notes on the Maya architecture and stelae, including plans and sections of the two standing buildings. The pottery from the Maya ruins consists of a small collection of pre-Old Empire sherds, a large collection which seems immediately to antedate the pottery from the Puuc area, and a small collection of a period contemporaneous with the Mexican period at Chichen Itza.

At Acanceh the best sherd collections obtained came from the base of the pyramid which is surmounted by the building bearing the well known stucco façade (Eduard Seler, *Die Stuckfassade von Acanceh in Yucatan*, *Sitzungsberichte der Königlichen Preussischen Akademie der Wissenschaften*, vol. 47, pp. 1011-1025, Berlin, 1911). The collections have not been sorted as yet, but are known to contain material ranging from pre-Old Empire times through the Mexican period. The pottery resulting from Mr. Andrews' clearing of the buildings surmounting the pyramid may allow these buildings to be fitted into the ceramic succession. A preliminary check of the material indicates that collections deposited after construction of the building with stucco façade antedate the Puuc period.

A large quantity of pottery was excavated from Mayapan, and a collection was obtained from the cenote of the near-by town of Telchaquillo. The Telchaquillo pottery is all post-conquest. The Mayapan collection contains small groups of pre-Old Empire and Old Empire Peten, and of Puuc period pottery from the bottom

of a trench sunk in the mouth of a cenote. Above this shallow deposit, pottery of the Mexican period of Chichen occurred mixed with, and finally superseded by, a deep deposit of redware of later date. A series of trenches dug near buildings throughout the main group of the ruin produced collections in which late redware preponderates. Several of the buildings have since been cleared and mapped by Mr. Andrews. The redware found at Mayapan corresponds to redware of the latest occupation of Chichen Itza, an occupation which at the latter site left little pottery and few if any architectural remains. The Mayapan deposits contain a fine orange ware which is stylistically the immediate descendant of the "X" type fine orange found at Chichen Itza (G. W. Brainerd, *Revista mexicana de estudios antropológicos*, vol. 5, nos. 2, 3).

The final field trip of the season was made to Ticul, Dzan, and Mani. Modern pottery making was studied at Ticul, and excavations were made in the environs of the three towns. Classification of the extensive collections made is as yet incomplete. The town cenote at Mani yielded a sequence ranging from a horizon to which we have thus far recognized no affiliations, through pre-Old Empire, through the Puuc and later periods, into heavy post-conquest deposits. Deposits on the grounds of the historic Mani church and monastery present an extensive Spanish colonial sequence, ranging from vessels closely related in form and ornament to Dzibilchaltun specimens, up to modern times. These collections are rich in Mexican and European glazed wares, and we hope for accurate dating of the associated native wares from this part of the sample. Other excavations chiefly in chultuns in Dzan and Mani and near Ticul yielded samples of the Mexican, Puuc, and later redware periods, of which samples from this part

of the country were previously lacking in our collections.

A summary and discussion of the chronology in its present status may be set down here, always qualified by the unfinished nature of the work and by the sparsity of samples over the large areas covered. During the periods above called "pre-Old Empire" the Yucatan Peninsula formed part of the range of a more or less homogeneous culture, extending over a large area which included the Peten. A major part of our Yaxuna pottery of this period was accepted by Mr. Smith as very similar to the Uaxactun pottery. The Yucatan collections contain pottery of this kind from almost every large site sampled. Certain pottery types in the Yucatan sequence which may tentatively be equated with early Tzakol show definite similarities to central Mexican pottery of the Early Ticoman period. The Yucatecan periods which equate with Tzakol and Tepeu I vary throughout the peninsula, having but a minority of their elements in common with each other and with the Peten. Peten polychrome tradewares occur in small percentages, and stand out sharply from the native wares. The period herein called Puuc follows the above and is characterized by the dominance of slateware, the antecedents of which appeared in the preceding periods. This period is quite uniform throughout Yucatan, as are the following periods up to the conquest.

An interesting side light on pre-Old Empire architecture is furnished by the contents of three trenches dug in the lower slopes of a large pyramid (15-20 m. high) at Yaxuna. The trenches were so dug as to pass through only post-constructional refuse and post-occupational slump. The pottery, beyond a few late surface sherds, is exclusively and typically of the pre-Old Empire period. Yaxuna, with its evidences

of long and early occupation and its suggestion of influence on Chichen Itza (S. G. Morley, Carnegie Inst. Wash. Pub. 501, pp. 546-547), should certainly repay excavation.

Our large collections from the Puuc region sites of Labna, Sayil, and Kabah contain no pottery equivalent to that of the Mexican period at Chichen Itza. Uxmal contains only a small fraction of 1 per cent. Thus these sites must have been abandoned before, or at the time when, the so-called Mexican period reached Chichen Itza. North of the Puuc hill range near Ticul, however, as well as north of Merida, and at Mayapan and Chichen Itza—widely separated sites—the Mexican period is represented. The rise and major occupation of Mayapan coincided with the decline of Chichen Itza. This fact is proved beyond reasonable doubt by stratified deposits at the two sites.

The collections on which we have worked until now contain no deposits dating from the transition between the Mayapan and the colonial periods. The color and finish of the earliest colonial slipped ware in our collection and that of the Mayapan pottery are very similar, but there are various changes in forms between the two periods. The small collections we have seen from Tulum definitely belong to the Mayapan period. Tulum was probably occupied at the time when the first Spaniards saw it (see S. K. Lothrop, Carnegie Inst. Wash. Pub. 335, for a discussion of the evidence). Tradition places termination of the occupation of Mayapan at about 100 years before the conquest (Diego de Landa, *Relación de las cosas de Yucatan*), and the ceramic evidence certainly does not refute such a dating.

As can be seen from the above data, the purpose of this season's work is on the way to accomplishment. We have every

reason to believe that by the end of the year a ceramic sequence equating with the Peten ceramic sequence and extending to the colonial period in Yucatan will be available from the material already excavated. In addition, a re-examination of the long-held theory that the major cultural development of Yucatan coincided with the decline of the Old Empire has been made advisable by the increasing evidence that Yucatan supported a considerable, widespread, and culturally advanced population during and before the time of the Maya Old Empire, and that this population in most cases used the same architectural centers, even the same pyramids, as did the people of the heretofore emphasized New Empire. There is no evidence of a major break in Yucatecan pottery tradition between the times of the Old and New Empires, and certainly no evidence of a sudden influx of Peten Old Empire influence during this period, when a migration either cultural or physical into Yucatan has been thought to have occurred.

The pottery collected this season has added several new wares, and extensive data on form and decoration, to the known Maya ceramic repertory. Perhaps more important have been the stratigraphic data which have permitted the chronological placing of many kinds of pottery previously known only from isolated sherd samples and whole pieces. Data on the variation between samples of the same ware gathered from various localities have added to our knowledge of cultural distribution and exchange. The continuance of the policy of placing the architecture in the ceramic chronology by its accompanying pottery has been made possible in several instances this season through the work of Mr. Andrews on three of the sites included in this report.

This study should represent but the be-

ginning of more intensive and illuminating work. It has not been conducted as an end in itself, but as a tool to aid in the unraveling of the broader aspects of prehistory in the Yucatan Peninsula. The necessarily involved and time-consuming work now nearing completion should permit the approximate dating, or at least the placing in an anchored chronological sequence, of any ruin, standing or fallen, in the area. Only two of the six Yucatecan pre-conquest periods tentatively outlined in this report are at all well known, the Puuc and the Mexican. Architectural work on the immediately preceding and following periods has recently been begun by Messrs. Pollock, Shook, and Andrews.

The present ceramic sequence is merely a dating outline. The order of the periods described has been stratigraphically proved, but much could be gained by further study of developmental changes between the periods, cultural interconnections, regional variations, and craft techniques. Further ceramic studies should go hand in hand with the archaeological excavation necessary to furnish a complete picture of the several horizons, the chronological placing of which has been indicated by this survey.

YUCATAN: ARCHITECTURE

E. W. ANDREWS

It is curious that the most heavily populated and geographically best-known section of the Yucatan Peninsula has remained almost entirely unstudied by the archaeologist. The ruins on the low plain to the north of the Puuc hills and to the west of Chichen Itza are represented in scientific literature by only the briefest references.

During a stay in Yucatan from December 1941 through June 1942, Mr. Andrews carried out preliminary studies at ten

ruined sites within a radius of 40 km. from Merida. At three of these, Mr. Brainerd undertook stratigraphic excavations for pottery, and at certain others surface collections were made and subsequently examined by Mr. Brainerd.

Perhaps most interesting of the season's finds was a group of sites indicating widespread architectural activity in northern Yucatan during early Old Empire times. These illustrate a style of temple architecture rigid in itself and distinct from the elaborate patterns of later pre-Mexican construction on the northern part of the peninsula. The chronological separation of the distinctive early and late styles is attested by actual superposition of buildings, the occurrence of transitional forms, and the association of distinct pottery types with the two architectural styles.

The early architecture is distinguished by a special structural technique. Wall masonry is of large, roughly faced blocks, leaving little or no space for cement hearting between the two faces. Vaults are of deeply tenoned flat slabs, apparently never pre-shaped, set in roughly corbeled courses with much fine rubble and cement. Wall faces are evened with considerable spalling, but vault faces are composed entirely of it, as the crude ends of the flat slabs offer no regular surface. Wall and vault surfaces were finished with a thick coat of plaster. Neither wall nor vault shows any suggestion of veneer.

The form achieved is both constant and simple. Basal moldings either are absent or are composed of a single course of rough blocks. Medial and superior moldings consist of a single rectangular member. The upper façade is normally covered with stucco designs in deep relief, which often extend onto the moldings. Carved stone is never used in façade decoration.

Later pre-Mexican architecture of the region is characterized by the use of very

finely squared and faced stone in a thin veneer over a rubble core, both in wall and in vault. No spalling was needed, and a thin coat of plaster sufficed to form a very smooth surface. Basal moldings, usually complex, are almost universal. Medial and superior moldings follow a three-member pattern, the upper and lower elements triangular in section. The upper façade is characteristically heavily adorned with mask panels or a variety of designs made up of a mosaic of small carved elements; where stucco relief is found, it is secondary.

Excavations in a small section of the acropolis at Acanceh revealed that the famous temple with the stucco reliefs belongs to the earlier pattern. It was originally built close to the north edge of a truncated pyramid about 8 m. high. Later, the platform was extended some 60 cm., and a new face added to the pyramid, the sides of which were covered with white stucco and painted with designs in red. A further stage of construction extended the platform a considerable distance farther north; and on this addition, some 50 cm. above the original floor level, was built the long, narrow building facing the Stucco Temple. The new edifice, although retaining the essential block-wall and slab-vault structural technique, varied somewhat in external form. It stood on a 35-cm.-tall, single-member basal molding, and although retaining the simple rectangular medial and superior moldings, replaced the strongly retreating upper façade of the Stucco Temple with a taller vertical one. Excavation showed that during the use of the court between these two structures, the floor level was raised five times. Finally, both temples were filled with rubble, their doorways were sealed with masonry of the early type, and the entire area was filled in to the level of the roofs to serve as foundation for buildings in the later architectural style. This

final phase is represented by no standing rooms on the acropolis, but is evident from an abundance of carved stone façade ornaments, typical veneer wall blocks, finely cut, deeply tenoned vault stones, and full-width doorjambs. Associated with each of the developmental phases mentioned were sealed deposits containing potsherds which should be correlatable with Brainerd's more extensive stratigraphic material from the slopes of the acropolis. A preliminary examination indicates the probability that all stages through the filling-up of the court between the two early temples belong to pre-Puuc times. It is probable, moreover, that the large pyramid in the city plaza, originally covered by a later structure but now considerably exposed, also belongs to the early horizon. Visible fragments are characterized by the use of inset stairways, rounded, inset corners, a lack of finely cut stone, and the use of large panels of stucco relief. The plan is strongly reminiscent of that of early Peten substructures.

As early as 1911, Seler suggested that the buildings at Acanceh were earlier than those generally known in Yucatan. He also pointed out a strong resemblance between Acanceh architecture and that of Ake and Izamal to the north, and suggested that the latter sites might be assigned to an early period. Acanceh and Ake, both large ruins, are conspicuously ignored in the conquest-period historical traditions of the local natives. Landa states in regard to Izamal, "There is no remembrance of their builders and they appear to have been the first." During the present season, brief visits were made to Izamal and Ake. The majority of remains at both sites are definitely not in the Puuc tradition, which is easily recognizable even in the debris of wholly fallen buildings. Nor do they consist of the entirely uncut stone whose use followed the abandonment of

fine veneer in Yucatan. Substructures and, in some cases, buildings were made of great, roughly faced cubical blocks differing only in size from those of Acanceh and other early sites. The stucco decoration of the Izamal pyramids is remarkably similar to that of the mound in the plaza at Acanceh. Finally, Brainerd states that sherds from below the plaster floor of one of the final additions to the mound complex south of the Convent of San Antonio at Izamal are referable to the basal-flange horizon in the Peten. This reference is paralleled by the orderly distribution of ruins at Ake around rectangular plazas, an arrangement characteristic of the Peten sites but not found in the cities of the Puuc and Mexican horizons in Yucatan.

Evidence that these differences are chronological rather than geographical is to be found at Cuca, 10 km. east of Ake. Here the remains are entirely of buildings in highly evolved Puuc style with no trace of the megalithic or block construction discussed above.

Ten days were spent at the ruins of Dzibilchaltun (also locally known as Xlakah), 15 km. north and slightly east of Merida, where Brainerd was conducting ceramic excavations. One standing temple there belonged clearly to the early style both in structural technique and in external form. But a number of minor traits hinted a possible developmental transition to the Puuc style. The structure had a low basal molding, and the wall stones were more finely cut than those of Acanceh, although showing no tendency toward veneer. The spring course of the vault was of very carefully faced stone, in strong contrast with the rough slabs of the vault itself. The end walls carried a thin false vault spring, a characteristic of Puuc architecture found in neither of the early temples at Acanceh. Pottery from between two floors

in one of the rooms has been tentatively described by Brainerd as immediately antedating that found in the Puuc sites. This earlier architecture seems to have included the greater part of the construction at Dzibilchaltun. Visible fragments of a filled-in and almost completely buried structure in another part of the site show identical masonry and outer façade form, and indicate that at least large parts of an elaborate stucco façade similar to that at Acanceh remain intact under later construction. Other lower wall and vault fragments are in this tradition, and the general plan of the site is characterized by Peten-like aggregations of mounds around orderly plaza systems. However, a few carved façade stone elements strongly reminiscent of Mexican-period Chichen Itza art bespeak at least some later occupation. These remains are very common in a single court at the eastern edge of the site, and rather rare elsewhere. Although a number of glyphic stelae are too badly damaged to offer any hope of translation, it is clear that none carried Initial Series.

About 40 km. west and slightly south of Merida and 6 km. southwest of Kinchil are the ruins of Tzeme, a very large site, covering several square kilometers. A large part of the town of Kinchil and the neighboring hacienda of Santa Maria has been built with stone taken from its monuments; and two grotesque life-size human statues from Tzeme have been removed to the Merida Museum. Although no standing buildings remain, two periods of occupation are evident. At the center of the site is a group of tall pyramids around a rectangular plaza. Near by are several groups of lower pyramids similarly arranged around smaller plazas. Atop these mounds are vestiges of small structures in the block-wall and slab-vault tradition, entirely lacking carefully cut stone. In the center of the plazas, however, and scat-

tered outside the central area are numerous remains of distinct rubble-and-veneer structures with carefully squared full-width jambs, specialized vault blocks, and a variety of sculptured façade elements. These buildings clearly belong to either the Puuc or the Chichen Mexican period.

Reports were received of the small site of Chuhku, about 15 km. southeast of Tzeme, containing at least one well preserved standing temple. Many residents of Kinchil can serve as guides.

Through the kindness of Don Fernando Cervera, it was possible to spend a number of days at the large ruins on the Hacienda Yaxcopoil, 25 km. south and slightly west of Merida. The ruins, about 1500 m. east of the hacienda buildings, seem to have been occupied from very early times through the Puuc and Chichen Mexican periods. Although no excavation was undertaken, much pottery from the latter periods was found on the surface. A small amount of red lacquer ware may indicate a short overlap into the last phase of pre-Spanish culture, or a small continuous population in that era. The central group of ruins is distributed around a long, narrow plaza, at one end of which is a pyramid approximately 12 m. high, ascended by four stairways. Atop the complete ruin of the superstructure is a geographical bench mark with the legend $N 20^{\circ} 45' 05''$, $W 89^{\circ} 42' 18''$. This large mound is called Tanmul, meaning "Central Pyramid," by which name the site is occasionally known. Present superstructure debris in the central group is characterized by a quantity of veneer stone, but this may be of secondary origin. About 250 m. south of this complex is a large, low platform mound bordered by four ranges of rooms surrounding a central court. Several rooms of the northern range are still standing and locally called Aka'na ("House in the Dark"), by which name the whole site has also

been known. Several phases of construction are apparent. An original five-room structure was built in style clearly transitional between the early and Puuc periods. The lower walls are faced with a poorly cut, irregular veneer, but the vault is made of flat, almost unfaced blocks so crudely set that the face consists largely of spalling. Moldings are complex but still rectangular in section, varying in form as a support for elaborate panels of deep relief in painted stucco which cover the upper façade zone. There is no carved stone. In two later stages, a series of rooms was built around this unit in a very different manner. Their rubble walls bear a thin veneer of finely cut, beautifully squared stone laid in perfect courses. Vaults are of the characteristic "boot-shaped" and beveled blocks, equally carefully set; and the upper façade zone was covered with panels and masks in carved stone mosaic. The outer corners bear on each face a line of carved rosettes from medial to basal molding. The doors, simple in the interior structure, become triple, with jambs and round pillars carved in typical Puuc style. The Aka'na will richly reward future excavation, for in the construction of the later rooms, the stucco façade of the older temple was carefully sealed in and remains largely intact. Remains of the later Puuc period architecture are distributed generously over the site, as are those of the following era of Mexican influence. Several long, low mounds bear a central row of altars formed of crudely cut megaliths, and have no trace of further masonry superstructure. Another common form of building is the round-columned, flat-roofed colonnade of Mayapan type, whose walls (as at Mayapan) are of crude block rather than veneer masonry. This fact, in connection with the small amount of red lacquer ware in surface pottery, indicates Yaxcopoil's importance for future study as pos-

sibly spanning the gap between the veneer tradition of the Puuc and Chichen Mexican periods and the uncut block masonry which later replaced it. This possibility is not known to exist at any other site on the peninsula.

Minor excavations were undertaken at one further ruin apparently occupied in pre-Puuc times. This site, 500 m. east of the Merida-Uxmal highway at Kilometer 39.5, is on the hacienda of Sihunch'en, whose name it has been given. Recently there were a number of standing buildings, but these have been in large part demolished and their stone ground up to resurface the near-by highway. Fragments of two buildings were left, both of which seem to be in the earliest architectural tradition. Walls are of large, coarse blocks with no rubble fill, vaults of the familiar unprepared flat slabs. No basal molding was used. Medial and superior moldings were one-member and rectangular. As usual, a lack of cut stone accompanies an elaborate stucco façade, in this case largely fallen. One building had but a single long, narrow room, colonnaded in front with very crudely rounded stone columns without pedestal but with a roughly squared capital, on which rested very crude stone lintels. The total door height was only 122 cm. Masonry in both buildings is much cruder than any observed elsewhere during the present season. It may reflect relative antiquity, or merely a lack of architectural skill at this small site. Not enough pottery was found to offer much clue to dating, although a few sherds were of pre-Mexican slate which could be assigned to either Puuc time or slightly before.

Another period of Yucatan history came under study in the course of a month's work at the ruins of Mayapan. Eight buildings were either largely or entirely cleared; and a number of minor excavations served to round out the picture thus

obtained. The site and its surrounding wall were mapped by Patton in 1938 (cf. Year Book No. 37, pp. 141-142).

A minor early occupation of the site is indicated by a number of re-used, finely cut stones in the buildings of the central group. No structures of this period remain, however, although it is possible that an unexcavated interior building immediately below the present superstructure of the Pyramid of Kukulcan (Structure 10) may belong to that horizon. These remains probably correspond to an underlying stratum of pottery (about 8 per cent of the whole) found by Brainerd to be similar to that of the Mexican period at Chichen Itza.

The vast majority of remains at the site consist of small unit shrines and colonnaded palace-type structures employing either thin-drummed round columns or anthropomorphic supports for flat beam-and-mortar roofs, as did a few atypical structures whose plans were almost certainly copied from Chichen Itza prototypes. The resemblance of the large round tower at Mayapan to the Caracol at Chichen has often been mentioned. The latest superstructure of the great pyramid at Mayapan is identical in plan with the Chichen Castillo, although very differently constructed and with unvaulted roof. Two small round temples excavated had ground plans similar to that of the Casa Redonda at Chichen.

Except where a few stones were re-used from the earlier period mentioned, both walls and vaults at Mayapan were constructed of completely uncut, rough blocks, with no tendency toward veneer. No prepared outer face is recognizable on blocks in fallen debris, and the absence of cubical form made coursing next to impossible. Although no façades at Mayapan stand as high as the medial molding, it is evident from debris that the profile was

normally that of a single two- or sometimes three-member molding with restricted upper zone, and the elaborate carved stone mosaic so typical of earlier-period façades was absent.

The major occupation of Mayapan may be clearly assigned to a period later than that which at Chichen Itza is represented by the architectural efforts seen at the ball court, Castillo, Temple of the Warriors, and related structures. But certainty as to whether architectural effort had entirely ceased at Chichen during the Mayapan period must await the discovery of specific associations between certain late structures at Chichen (the Temple of the Initial Series, the Temple of the Interior Atlantean Columns, etc.) and deposits of pottery from one of the two periods. Although certain of the larger temples at Mayapan undoubtedly drew inspiration for their plan directly from Chichen, the constructional techniques of the two sites are uncompromisingly distinct. The earlier veneer traditions persisted at Chichen through the end of architectural activity. On the other hand, the relation between Mayapan and the cities of the east coast of Yucatan is unmistakably close. Structural techniques are almost identical, and parallels in external form are striking. Both groups emphasize the colonnaded palace with round columns and anthropomorphic roof supports; and the simple unit shrines which form a large part of the structures in the two groups follow closely the same plans. The lack of carved stone façade decoration in the two areas parallels the restriction of the upper façade zone and simplification of the molding pattern. Other details such as walls surrounding the cities (Mayapan, Xelha, Tulum) imply further connection. It will be seen in Brainerd's report that available ceramic evidence equally strongly indicates that the so-called "Mexican period" remains at

Chichen Itza form a horizon earlier than that of Mayapan and the east-coast cities.

The above considerations suggest that the conventional division of peninsular culture into a "Maya period" and a "period of Mexican influence" by no means delineates the significant phases of its development. In the evolution of art, architecture, and ceramics, three quite different divisions seem clearly indicated by data now available:

I. The earliest architecture in Yucatan is characterized by walls of large, crudely faced blocks, vaults of flat, entirely unprepared, corbeled slabs, and a complete absence of carved stone façade decoration. Rough wall and vault faces were smoothed by a thick coat of stucco, which was also used in the execution of elaborate reliefs in the upper façade zones. This period of occupation is seen at Coba in the east, and is strongly represented in the Merida region. Pollock and Shook have described contemporaneous and very similar architecture at sites running from Maxcanu in the Puuc to Bakna in central-western Campeche. Brainerd characterizes associated ceramics by absence of evolved slateware, and affinities with Tzakol and perhaps Tepeu I in the Peten. The lower limits of this occupation are at least as early as the end of cycle 8.

II. Sometime in the second half of cycle 9, a drastic change took place in north-peninsular culture. From block-wall and slab-vault architecture, there was a sudden transition to rubble construction covered by only a thin veneer of finely cut stone. The simple external building form gives way to the complex but rigid patterns associated with the architecture of the Puuc region, where the new forms may have developed. The stucco façade was replaced by elaborate panels of carved stone mosaic. Along with this change in architecture came an equally striking development of

slatewares in pottery; the earlier wares disappear, and ceramic resemblances to the Peten are confined to tenuous similarities to Tepeu. This new culture does not seem to have been of foreign introduction, for the new architectural and ceramic forms had their origins in the previous period. Early in cycle 10, continental Mexican influences appear at Chichen Itza, either coincidentally with or shortly after the abandonment of the Peten cities and those of the Puuc. During the so-called Mexican period at Chichen Itza, these influences altered the superficial aspects of local culture, but notably failed to affect to any extent the fundamental architectural, sculptural, or ceramic techniques. Architectural innovations are seen in such features as replacement of the basal molding by a battered lower zone, and the prominent use of serpent columns and stairway balustrades. But the basic construction of rubble buildings with a thin stone veneer remained unchanged until the abandonment of the site. New religious motifs in sculpture accompany no great change in style. Finally, although imported trade pieces make their appearance in connection with changes in shape and design in local pottery, slatewares maintain undisputed dominance.

III. The second great change in Yucatan culture took place about the middle of the fourteenth century, and was quite as radical as the first. Veneer was abandoned, to be replaced by the use of uncut, rough blocks in a masonry more similar to that of modern native houses than to any earlier archaeological remains. Vaults are made of crude masonry, but are no more frequently used than the flat beam-and-mortar roof. A new temple form, the unit shrine, becomes numerically dominant. The colonnaded palace, which first appeared late in period II, takes on new form. Columns become universally round

rather than square, and anthropomorphic roof supports are common. In sculpture, forms appear which bear little resemblance to previous artistic efforts of the Maya. In pottery, the slatewares vanish, to be replaced by what Vaillant called "red lacquer wares" and (perhaps later) crude figurine incensarios. The new architectural forms persisted for the century and a half or two centuries until the Spanish conquest.

GUATEMALA: KAMINALJUYU

E. M. SHOOK, A. L. SMITH

In 1936 and 1937 excavations were carried on at two mounds of the great archaeological site of Kaminaljuyu in the outskirts of Guatemala City (Year Books Nos. 34-36). One of the mounds (A) was completely dissected. It proved to contain eight superimposed structures and to overlie six pit tombs rich in pottery and jades. The body of the second mound (B) was not investigated, but three tombs were found below its frontal platform and a modern cut on one side indicated the probable presence of several structures built, as in Mound A, one above another. In the course of preparing the results of the above work for publication, it became obvious that more data were needed on several important points concerning architectural and mortuary practices. It was therefore decided to excavate Mound B, a task undertaken by Mr. Shook and carried out from November 1941 through May 1942.

The mound before excavation was a conical hillock some 35 m. in diameter by 7.5 m. high. A vertical slice had been cut, in recent times, from its western slope; and, some years before, a deep, wide trench had been run in from the southeast by treasure hunters. Mr. Shook's opening trenches were pushed inward from the

north and south, these sides being chosen because the later structures in the mound were known to face west, and it had been learned, during the work on Mound A, that tombs and caches, stairways, and other important architectural features were to be found on the front and could more safely be reached by lateral than by frontal approach. The south trench at once encountered the basal step of a pyramidal substructure of puddled clay faced with a layer of lumps of pumice and coated with *pedrin*, an almost concrete-hard mixture of lime and small pebbles. The trench was pushed through this, revealing a second building of identical construction, which in turn was penetrated as far as a third building of pure adobe. There was thus disclosed a sequence corresponding to that found in Mound A, whose two outermost elements had pumice-and-clay heartings with *pedrin* finish, the third being of adobe.

At this point it was felt that enough was known of the mound's make-up to permit the frontal features to be investigated. The basal step of the outermost building (Structure 5 in the final enumeration) was accordingly followed around the southwest corner and across the western face to its abutment against the remains of the frontal stairway. The basal step was also located on the north and followed around the northwest corner to the stairway. The same method was employed in outlining Structure 4, and in laying bare the south side of the adobe pyramid, Structure 3. At the same time a third penetrating trench was run in from the east, encountering and passing through two more adobe structures, Nos. 2 and 1.

As to Structures 1 and 2, little was learned, for they were seen only in median section in the sides of the narrow penetration trench. They appeared to have

been low pyramids, parts of which had been cut away in the course of building the later units of the complex. Structure 3, however, was relatively well preserved. It was an adobe pyramid with basal measurements of about 30 by 30 m., a broad adobe stairway with heavy balustrades mounting its western face. The upper part of the stairway had been destroyed by the pot-hunters' trench, but a small area of the summit platform remained.

Structures 4 and 5, though inferior in construction to the corresponding units of Mound A, yielded the hoped-for information as to the pumice-and-*pedrin* type of building. It was learned that it had a low basal step, a lower sloping zone topped by a slab-supported cornice, and a more nearly vertical second zone divided by moldings into rectangular panels. At the front a stairway mounted to a jutting platform, on which there apparently was located a small shrine. A second flight, of which only traces of the lowermost steps remained, led upward, doubtless to a temple on the summit platform.

Two tombs were found: a small one south of the foot of Structure 5's stairway, and a very large one in front of the foot of the stairway of Structure 3. The small tomb contained the skeleton of an aged male, the bones of a child (probably a sacrifice), some jades, and a number of pottery vessels. The large grave was evidently that of an important personage, as it was more lavishly stocked with mortuary equipment than any of the other ten tombs so far opened at Kaminaljuyu. The principal occupant, seated cross-legged in the center of the tomb floor, had been literally covered with ornaments of jade and shell; a necklace of 280 jade beads was about the neck. In front of the body was a pile of very fine pottery, many of the pieces coated with stucco and beautifully painted. The skeletons of three young

persons, evidently sacrificed at the time of their master's burial, lay toward the walls of the tomb. Near one of them was the finest single object recovered, a pyrite-incrusted plaque whose slate backing bore an intricate carving, the central elements being two small figures standing on either side of an altar, from which rises what appears to be a conventional tree.

Although the finds in this tomb were most spectacular, the most important results of the Mound B excavation were the data recovered as to architecture and as to the succession of pottery types. Great numbers of sherds were found in the fill. These were largely of the Esperanza phase, contemporaneous with the erection of the structures, but among them were many fragments of Miraflores pottery. The latter, representing the oldest ceramic horizon so far identified at Kaminaljuyu, had, of course, been scraped up with earth used for the fill of the various structures. After the mound had been abandoned as a place of worship and had fallen more or less into ruin, there accumulated on and about it a heavy stratum of occupational debris containing pottery of two post-Esperanza phases which have been called Pamplona and Amatle. Although stratigraphic conditions were not clear, there is little doubt that Amatle is the older of the two. One component of the Amatle phase is plumbate ware, mostly in simple cylindrical forms. Similar plumbate was found in 1940 by A. L. Smith at San Agustín Acasaguastlan on the Motagua River, and more came to light in J. E. S. Thompson's excavations of the past season at El Baul on the Pacific coast plain. When these and other ceramic materials from highlands and lowlands have been studied and compared, it seems probable that the chronological and commercial relations of several important ancient Guatemalan cultures will become clear.

During the mapping of Kaminaljuyu in former years there had been noted at least nine constructions which, because of their elongated rectangular form, were surmised to be ball courts. In order to test this supposition, A. L. Smith, in 1941, ran a trench across the middle of one of the largest. The finding of two tenoned stone parrot heads, analogous to those of the Copan ball court, and of traces of sloping benches paralleling a playing alley settled the matter conclusively.

During the past season further excavation was carried on here, and two smaller courts were investigated. The original 1941 trench in the large court was re-opened and sunk to a depth of about 5.5 m. before sterile natural deposits were reached. Directly below the northern long wall, Mr. Smith exposed parts of two deeply buried earlier constructions. The upper one was of red-painted adobe, apparently with low vertical terraces. Its upper parts had been cut away in ancient times. An adobe floor, also painted red, extended outward from its base. Farther down was the southeast corner of a very well preserved building, probably a substructure. Its basal terrace had borne slab-supported moldings, torn away when the building was buried, but it, and what remained of a second terrace, were still covered with smooth, hard, red-finished piedrin. Well underneath this was a floor of packed adobe, under which, to subsoil, a distance of nearly 2 m., the deposit contained only Miraflores pottery, the earliest type so far found at Kaminaljuyu.

By the time subsoil had been reached, the rainy season was about to begin. Work was therefore suspended, but the trench was fenced and left open in case it should be possible to push the operation farther at some future time. Although removal of the tremendous overburden would be a long and costly undertaking, the investiga-

tion of the early buildings and of what may well lie below and behind them would undoubtedly yield invaluable archaeological information. We already know that there is a direct superposition of three types of structure and a stratification of Miraflores, Esperanza, and Pamplona-Amatle pottery. Because of the depth of the deposit and the sealing of several of its horizons by floors, there is likelihood of recovering unmixed samples, some of them perhaps exemplifying hitherto unknown transitional ceramic periods. Furthermore, the lowest floor may be connected with a structure dating from Miraflores times. The discovery of such a building would be of the greatest interest, for Miraflores structures, presumably ancestral to all later architectural developments in this region, are still entirely unknown.

While work in the deep central trench was going on, a pit was sunk in the southwest corner in a vain search for the tenoned stone head which, on the analogy of the Copan ball court, should have been found there. The digging, however, revealed, below the level of the court, a piedrin floor pierced by several large postholes, which indicated the former presence there of a building of perishable materials.

The second ball court investigated formed part of a small group just to the east. A trench was dug across its short axis, a little north of the center in order to cut into a mound resting on the western wall of the court. The upper part of the wall and the face of the mound proved to be terraced and to bear a piedrin coating.

The transverse trench, again carried to subsoil, yielded evidence of a long series of structural events, involving two rebuildings of the court; an abandonment during which a humus layer was laid down; and the excavation, perhaps through a still earlier fill, of a pit in whose bottom was a drain, slab-floored and -walled but with-

out capstones. A tenoned human head of stone came to light in the western extension of the trench.

The third court lies in a considerable group well to the east in a district called La Granja, where a real-estate development is now being undertaken. As part of the "improvement" a road was run through the court, cutting both end walls and passing down the long axis of the playing alley. This permitted observation, with relatively little digging, of the enclosing walls and the alley. The dimensions of the alley were determined to be 33 by 7 m. Remains of an earlier construction were laid bare. This, razed almost to ground level when the ball court was built, had originally been a multi-chambered affair without supporting platform. In its piedrin floor were postholes and on it were butts of several free-standing walls of moldmade adobes faced with pumice blocks and piedrin.

A number of finds were made at this court. Directly under the southeast corner of the playing alley were two plain redware bowls set lip to lip, probably a dedicatory offering. Near the center was a large tenoned stone snake head, which had obviously slipped down from the north-central wall. Several other heads and pieces of broken sculpture had come to light during the digging of the modern road. In the center of the court Mr. Smith encountered a filled pit which, seeming to be ancient, was believed to have served as a drain or sump. Well below the level of the playing alley, however, were the almost completely rotted bones of a horse, and below them the crushed remains of two pottery water jars. The horse bones, of course, proved the pit to be post-conquest, but their condition argued for very long burial, and the jars, when restored, were found to be of an unknown type, per-

haps ancestral to present-day Chinautla pottery. They are, in any case, the oldest "modern" vessels so far collected.

To sum up: Mr. Smith's investigations made it clear that the nine or more long rectangular constructions at Kaminaljuyu are ball courts, and have permitted identification as such of many similar ones at other sites throughout the valley of Guatemala. The ball court, indeed, is shown to have been perhaps more abundant in this region than in any other part of Middle America. As to the details of construction, data are as yet not fully satisfactory because, being of pure adobe, the courts have suffered severely from erosion and the growth of forest trees. It is known, however, that the playing alley was long and narrow, and that it had low, sloping side benches. It was closed at either end, thus lacking the expanded end zones characteristic of most other ball courts. Set opposite each other at the middle of the parallel side walls were two tenoned stone heads, usually parrot or snake, often with a human face in the open mouth. Whether these were placed vertically, as at Copan, or horizontally is unknown, as all were found fallen forward on the side benches. There was no evidence of stone markers in the floor of the playing alley. The courts seem to be sited without regard to the cardinal points.

GUATEMALA: PACIFIC COAST

J. E. S. THOMPSON

The considerable number of fine sculptures in the neighborhood of Santa Lucia Cotzumalhuapa, Escuintla, on the Pacific slope of the Guatemalan highlands, are of prime importance in determining the history of Mexican-Maya relations. The style, subject matter, and hieroglyphs of the monuments have long been recognized as of a distinctly Mexican cast, but the

chronological position of this Mexican enclave has been a matter of much speculation. The ruins have usually been attributed to the Pipil, a Nahuatl-speaking group, a part of which was settled in eastern Escuintla at the time of the conquest, but the question of when these sites flourished could not be solved without excavation.

At the end of January 1942, Mr. Ralph L. Roys, Mr. Thompson, and his photographer, Mr. William Webb, made a tour of the central and western parts of the Pacific coastal slope to decide on a place to excavate and to inspect sites and collections with a view to obtaining information on the general archaeological picture in this area. The most interesting outcome of this reconnaissance was the discovery of two stelae at a large site on the Fincas San Isidro Piedra Parada and Santa Margarita, near Acintal, in the southeast of the department of Quetzaltenango. Both stelae were carved in the easily recognizable style of Izapa (Tuxtla Chico), a site in southeastern Chiapas. One of them, however, had an Initial Series introductory glyph followed by the number seven, expressed by means of a bar and two dots. There was a plain surface immediately below, indicating that the number had not been associated with a glyph, but the rest of the surface has flaked off. This stela, therefore, falls into the small and very perplexing group of monuments which have numbers but no glyphs, and which, in the opinion of some archaeologists, are of extreme antiquity. It is difficult to hazard whether the complex scrollwork of this Izapa type denotes the over-elaboration of a primitive style or the sophistication of a late rococo development. Near by was a boulder carved with a kneeling figure, perhaps a ball-game player, in the style commonly known as Olmec. The site is large, and because of the diversity of styles

(there is also extremely crude sculpture there) and because plumbate sherds indicate that its occupancy may have been extended, excavation there might be well repaid.

Following this preliminary reconnaissance, Mr. Thompson and Mr. Webb proceeded to El Baul, a sugar plantation near Santa Lucia Cotzumalhuapa, where through the courtesy of Mr. Carlos Herrera, one of the owners, and Mr. Julio Garcia Salas, the manager, they were invited to stay as guests of the plantation as long as the excavations lasted. El Baul is of archaeological importance because among the sculptures found there is the Piedra Herrera, another of the group of stelae with numbers unattached to glyphs. This has been read as an Initial Series recording the very early date 7.19.7.8.12. It was desired to determine whether ceramic evidence bore out this early attribution, and it was also hoped to date the Cotzumalhuapan sculptural style, of which good examples also occur there, in terms of ceramics.

Considerable quantities of sherds were obtained, but, unfortunately, no clear-cut stratification. Two periods are, however, represented, and there are slight traces of a third. The latest, which includes plumbate vessels of simple forms, but not those which found their way in trade to remote parts of Middle America, appears to be coeval with the Amatlé horizon at Kaminaljuyu. The earlier is close to the Esperanza horizon of Kaminaljuyu. There were also a very few sherds which stylistically belong to the still earlier Miraflores horizon. One pyramid was partially excavated, bringing to light a very fine low-relief sculpture in Cotzumalhuapan style which represented the upper half of a deity or personage emerging from the body of a rather realistic crab. This pyramid also yielded two heads of snakes in the round,

a stone with the date 4 Quiauitl, the glyph being represented by a full-face view of the head of Tlaloc, and a stairway of large, well dressed stone blocks. The pottery has not yet been studied in detail, but at least it can be said that among the very few sherds in the soil in front of and level with the butt of the Piedra Herrera are included some which are very probably of the later horizon.

Pottery from Tiquisate, Suchitepequez, is almost exactly the same as that of the later period at El Baul, and other sites on the Pacific coastal slope have several ceramic types in common with El Baul. At the site of El Castillo, about 1.5 km. from El Baul, the presence of round monolithic columns was noticed. Some of these were in the soil at the foot of a mound, others had been set up around the hacienda building. Visits were paid to the neighboring fincas of Pantaleon, Los Tarros, Aguna, and Xata, where archaeological material was inspected. The many examples of sculpture at Pantaleon are well known, but it is not generally realized that some of these pieces came from El Baul and neighboring fincas.

Mr. Thompson spent the month of April in Guatemala City making notes on the sherd material from El Baul in order to avoid the necessity of shipping the collection. One interesting point has developed, namely, that the sherds of plumbate ware, many of them poorly fired, it would seem, are of forms such as shallow bowls and simple cylindrical vases. None are of the more elaborate effigy vessels or composite silhouette jars which are so widely distributed. Since Mr. Kidder found a similar situation in the Amatlé horizon at Kaminaljuyu, and in view of the associated pottery at both sites, it seems not improbable that these simple forms of plumbate are anterior to the development of export to distant markets.

During a brief reconnaissance in the highlands, in company with Mr. Roys, two important groups of ruins near Sacapulas were visited. One, Rio Blanco, on the peninsula formed by the confluence of the Blanco and Negro rivers, was found to have an oval pyramid and a ball court in a good state of preservation. The second, Chutix Tiox, situated on a steep hill to the north of the Santa Cruz Quiche road and about 4.5 km. from Sacapulas, has some remarkably well preserved buildings, including a *monoztli* (a small pyramid-like platform) with the plaster still in position on most of the almost perfect surface, and a room about 24 m. long, the back wall of which was standing to a height of about 2.7 m.

NICARAGUA

F. B. RICHARDSON, K. RUPPERT

As was recorded in the last annual report, tracks of barefooted human beings and of various animals and birds are from time to time found during quarrying operations in a deeply buried volcanic stratum at El Cauce in the vicinity of Managua. In 1941 Mr. F. B. Richardson investigated a recently discovered set of these footprints. The layer in which they occur was the product of an eruption from some vent on higher land. From it a sheet of semiliquid mud flowed down toward Lake Managua, and while this was in process of hardening, but still plastic enough to receive perfect impressions, the people and animals passed across it. Almost immediately thereafter a fall of dry cinders covered and preserved the tracks. Subsequently the area was blanketed by other mudflows, now, like the footprint stratum, hardened to stone. Later the entire series of layers was cut through by a small stream whose bed, in course of time, became filled with silt and water-rolled

boulders. Still later there was a heavy fall of pumice, followed by an interval of quiescence with further stream erosion, deposition of humus, more pumice falls, and, finally, a cessation of volcanic activity and the deposition of the present topsoil to a depth of 1.25-1.50 m.

That a long time must have elapsed since the making of the footprints is certain; but until the volcanological studies of Dr. Howel Williams, of the University of California, who is cooperating with Mr. Richardson in this investigation, can be carried farther, no estimate of the period involved is possible. In the meantime, however, Mr. Richardson has continued work at the site, and Mr. Karl Ruppert devoted the past season to study of the archaeological remains found in the recent surface deposits.

The area of the original discovery was widened and the tracks were followed for a distance of some 20 m. A careful count showed that 17 persons had passed, going in a straight line toward a low promontory that juts into the lake. The tracks originally identified as those of deer have since been shown to have been made by a large peccary.

Another discovery of animal prints, made during the past season, promises to be of great interest, both archaeologically and paleontologically. At a stone quarry on higher land some distance away there has been exposed a sequence of mudflows, apparently from the same source as those of El Cauce. The lowest of these, which may well represent the identical flow seen at the base of the El Cauce series, was found by Mr. Richardson to contain tracks of a large cloven-hoofed creature. Latex casts were submitted to Dr. Thomas Barbour, of the Museum of Comparative Zoology at Harvard University, and to Dr. Paul O. McGrew, of the Field Museum in Chicago, both of whom identified the

prints as those of bison, an animal which seems never before to have been reported from Central America.

If man and bison, an animal certainly long extinct in the region, are found to have been contemporaneous, we shall have evidence of the high antiquity of the El Cauce footprints, which may indeed be the oldest traces of human occupancy yet found in Middle America. It is therefore outstandingly desirable to gain even the smallest scrap of knowledge as to the culture of these people. The prospects of such a discovery are, however, remote, as the surface on which they lived now lies buried under several meters of solid rock, pumice, and earth and is accessible only in the few relatively tiny spots where quarrying operations have removed the overburden. The vicinity of the footprints is not promising, as the pre-mudflow land thereabouts was a gentle slope, apparently an open and perhaps barren plain. As such it would have been ill suited for a dwelling place, and the chances of finding artifacts on it are very slight. But since the government drainage ditch made it possible to reach part of the old surface at one side of the footprint area, it seemed worth while to expose and search as much of it as was reachable. Some 60 m. of footprint stratum were accordingly removed and the top 30 cm. of the underlying deposit passed through a fine-meshed screen. Nothing, unfortunately, came to light.

Through the good offices of President Somoza, the site has been acquired by the Government of Nicaragua and a resident custodian has been appointed. Over the tracks Mr. Richardson has erected a permanent building, whose tiled roof protects them from the weather while its open sides permit their examination at close hand.

Although determination of the age of the footprints is primarily a volcanological

problem, a minimum date, archaeologically speaking, can be arrived at through study of the cultural remains in the superficial deposits, for the oldest of these must be much younger than what lies under the great accumulation below. Mr. Ruppert therefore devoted the season to surface excavations at El Cauce and elsewhere in the neighborhood of Managua.

The pottery-bearing level of brown soil at El Cauce is 3 m. above the footprint stratum, varies in thickness from 1.3 to 1.6 m., and, according to Dr. Williams, "while apparently of aeolian origin, much must have been laid down by running water." A number of pits and trenches were dug and yielded abundant sherd material apparently of a single not very remote period.

During the previous season a burial ground had been discovered east of El Cauce and south of the railroad tracks. In some of the boot-shaped jars were fragments of human bones. The area was re-examined during the current season. Although a number of caches of vessels were uncovered, none contained skeletal material.

A high point of land northwest of El Cauce protruding slightly into the lake seemed a likely place for a series of trenches. The yield of sherds was extremely small. In general the wares are similar to those from El Cauce. The number of sherds worked as net-sinkers was relatively large. Sherds obtained from trenches at Las Mercedes Airport, 9 km. east of Managua, were again of wares similar to those from El Cauce.

At the close of the season a mound to the east of El Cauce, on the property of Don Salvador Salgado, was examined. A pit in the top of the mound is said to have been made by pothunters. A trench on the north side extending from the valley floor inward to the center disclosed a rough stone-faced platform 50 cm. high

and 6 m. wide. The mound, 3.50 m. high by 10 m. in diameter, resting on this platform was faced with unworked stones. Near the center and 2 m. above its base was a cache of three vessels. The sherds, varying little from those at El Cauce, did however include several pieces of Usulután pottery, a ware which, in Guatemala and El Salvador, is found only in the earliest ceramic horizon. The presence of Usulután fragments, probably dating from a period long anterior to the erection of the mound and owing their presence there to accidental inclusion in its fill, argues for a relatively ancient occupancy of the Managua valley subsequent to the latest volcanic activity.

Analysis and interpretation of the ceramic material have not yet been made. A wide trade in pottery vessels is, however, attested by the presence of sherds of Honduranian (Ulúa Valley and Lake Yajoa) and Salvador wares. Over 75,000 sherds were examined and sorted, and a representative collection will be brought to the United States for final study.

CERAMIC TECHNOLOGY

ANNA O. SHEPARD

The study of plumbate ware has been the principal project of the year. This ware, important because of its wide distribution in Middle America and its consequent value for correlating occupations and establishing contacts, has for nearly 60 years been an archaeological enigma. The place of its manufacture is unknown, and postulates regarding that center have included such distant regions as Salvador and southwestern Chiapas. From the standpoint of ceramic technique it is the most highly developed Middle American ware known, yet its peculiarities have been completely misunderstood and erroneous speculations have gained acceptance

through frequent repetition. Technological analysis is therefore required. The ware also affords opportunity for a somewhat different approach from that which has been made in previous technological studies of Middle American pottery. In earlier work, pottery recovered from a single site has been analyzed for the purpose of defining occurrences. A considerable amount of time has therefore necessarily been devoted to the study of local wares of inferior quality which had no trade value and which consequently do not directly contribute to investigations of the interrelations of peoples. In the plumbate project, on the other hand, attention is concentrated on a highly specialized and widely traded ware. All its geographic occurrences and ceramic associations are being studied. We are considering the indications which paste gives of the place of its manufacture, the degree of variation in the materials used and the possibility of admixture of clays, the relative importance of firing method and properties of the clay in their effect on the quality of the surface, the frequency and method of imitation, the possibility of trade in raw materials, and the comparison of contemporaneous wares in composition and workmanship.

In this study it has proved advantageous to observe technological and stylistic traits simultaneously. The technological work has included analysis of the surface material, thermal experiments to learn what methods of firing were employed, and petrographic analysis of the paste. In the study of surface material, spectrographic analyses have been made of 15 samples, together with comparative analyses of 25 samples of common red slips. We have been fortunate in having the privilege of using the 35-foot grating spectrograph of the Massachusetts Institute of Technology. X-ray analyses of several samples have also

been made, by courtesy of Drs. Grim and Bradley, of the State Geological Survey of Illinois. These results, together with those obtained by microchemical determination of the three major constituents, definitely correct the idea that the vitreous appearance of the ware results from a lead glaze. The analyses also explain in large measure the distinctive surface qualities of this most unusual pottery. Except for the single analysis by Loeb in 1903, made before the development of refined methods of handling small samples, these are the only analyses ever made of the glaze material.

A series of firing experiments has been conducted to learn what temperatures and firing atmospheres would produce the peculiar hard, gray surface of the ware. Soft, red, underfired portions of plumbate sherds have been changed to the typical hard, vitreous surface in these experiments.

Because of the extremely fine texture of the paste, petrographic analysis has been more exacting and time-consuming than has that of other wares. The 150 sections studied are from several sites in the western Guatemalan highlands, and from Alta Verapaz, Salvador, and Chichen Itza. Various sherds thought to be either of mixed material or imitations have also been analyzed. The paste is distinctive in composition and unquestionably offers the best clue to place of manufacture of the ware.

In spite of the great importance of plumbate, its stylistic features have never been fully described, partly because published studies have, in general, been based on small collections. In order to correlate stylistic and technological features and to compare them with those of contemporaneous wares, it has been necessary to obtain from many sources the available data on style. This stylistic material will be included in the final report on plumbate. A record has been made and photographs

have been obtained of the plumbate vessels in the principal museums of the United States. Over 250 vessels are now represented in the file; the record includes profile drawings and detailed measurements from which basic proportions have been calculated, and data on surface qualities and workmanship. To facilitate the analysis of style, drawings have been made by Miss Janice Snow of incised designs, and such details of effigies as features and objects of adornment. The mass of stylistic data which has already been collected, when extended by field studies in Central America, will, it is hoped, serve to corroborate and strengthen the results of technological analysis.

SOUTHWESTERN UNITED STATES

E. H. MORRIS

Three seasons of field work among early Anasazi remains near Durango, Colorado, have been described in Year Books Nos. 38-40. Preparation of a report on these excavations and the objects exhumed has been the principal objective of Earl H. Morris and his collaborator, Robert F. Burgh, during the current year. This report has developed into a far longer undertaking than was anticipated. It is the aim of the authors to present the various categories of material from the Durango excavations in as thorough detail as they did for Anasazi basketry in their publication (Carnegie Inst. Washington Pub. 533) which came from the press in December 1941. To that end the specimens are being studied with extreme care, and the archaeological literature of the Southwest and neighboring areas is being combed for references which will shed light on the occurrence and distribution of the types into which they fall. There are several months more of work ahead before the report will be ready to submit to the editor.

During the 1941-1942 school year Mr. Burgh devoted part of his time to the teaching of courses in Southwestern and classical archaeology in the University of

Colorado. In the same interval Mr. Morris spent a number of weeks upon archaeological manuscripts submitted to him for opinion and revision.

SOCIAL ANTHROPOLOGY AND LINGUISTICS

R. REDFIELD, S. TAX, A. VILLA R.

The program in ethnology and social anthropology this year consisted of desk work rather than field enterprises. *The folk culture of Yucatan*, a book by Dr. Redfield summarizing the results of the research carried on in Yucatan from 1931 to 1936, was published in July 1941. Dr. Tax completed his report on the economy of the Indian community of Panajachel. This will form the first of three volumes on that community. The other two volumes are in preparation: that dealing with the Indian world view is about half done; that concerned with the social organization is in its inception. Dr. Tax also wrote a short article on race relations in Guatemala, prepared a short manuscript—to remain unpublished until further developed—dealing with what appear to be important differences between highland and lowland Maya cultures, and organized materials on Middle American ethnology in connection with a course on that subject which he and Dr. Redfield taught in the spring at the University of Chicago. At the end of the year, Dr. Tax left for Mexico City, where he was to teach a course in Maya ethnology, with special reference to ethnographic field techniques, at the Escuela Nacional de Antropología. It is his plan, following the termination of the course, to take a group of students to the Tzotzil community of Zinacantan in the state of Chiapas, to do field work in that little-reported Maya group. For these purposes the services of Dr. Tax have been lent by the Carnegie Institution to the Escuela Nacional.

With the assistance of their class at the University of Chicago just mentioned, Dr. Tax and Dr. Redfield began a collection and comparison of material on Middle American ethnology which might ultimately become a contribution to a handbook on that subject. It is planned also to prepare a selected bibliography.

Sr. Alfonso Villa R. spent most of the year in revision of his manuscript on the Quintana Roo Maya, which is now ready for the press. In May, Villa reached the small Tzeltal community of Dzajalchen in the municipio of Oxchuc, near Tenejapa, in Chiapas, with the intention of remaining there several months carrying on a general ethnological study of these Indians, who had been the subject of a brief published report based on a reconnaissance of their villages made by Villa in 1938. His first report from the field contained maps and censuses of the community chosen for study and information on social organization. Of interest is the fact he reports that each settlement takes its name from a cave wherein is housed a cross at which members of that settlement perform their religious rites; each tract of land in the settlement is considered the permanent property of this cross; the son (never a daughter) inherits the land with obligation to keep up the prescribed rites, and sale of a tract does not change its belonging to the traditional cave.

Sr. Juan Rosales, field assistant to Dr. Tax, spent the year in Chicago, continuing the preparation of his monograph on the culture of the Maya of San Pedro de la

Laguna in the midwest highlands of Guatemala. He was aided by support from the Rockefeller Foundation. He has completed the introduction to his work, and the chapters on technology and material culture, comprising almost 500 typescript pages. He will remain in Chicago at least until January 1, 1943.

As was recorded in the preceding annual report, Benjamin Paul, a fellow of the Social Science Research Council, went to San Pedro de la Laguna to study the same community investigated by Rosales, as an experiment in ethnological method. Mr. Paul spent a year in that village, and returned to the United States in December 1941. Having received funds from the University of Chicago to enable him to prepare his report, he set about this task at the beginning of the new year. Mrs. Paul, who accompanied him and did field work under provision made by the Committee for the Study of Dementia Praecox, Scottish Rite Fund, brought back unusual and interesting material on the socialization of the child.

A further contribution to the ethnological work of the Institution was made by the University of Chicago when it supplied a sum of money enabling Rachel Reese Sady to make a study of certain official Mexican records, with an evaluation of their usefulness to ethnologists. Mrs. Sady examined and, when necessary, transcribed or summarized the formal records made by national, state, and municipal governments pertaining to two communities known to contain a large Indian element but differing in most other respects. She then did enough field work in the first community (Ocotpec, in the state of Morelos) to enable her to form a judgment as to the extent to which conditions therein were reported in such records. The other community was one in Chiapas to which it is expected Dr. Tax will go in

the winter of 1943. Mrs. Sady is writing a report which it is expected will be a guide, for the investigation of Mexican aboriginal communities, to students who may wish to take advantage of formal governmental records as a part of their work.

Beginning July 1, 1942, the program of field research will be strengthened as the result of an important addition to the Division staff. Through an arrangement with Duke University, Dr. John P. Gillin, of that university, has become a Research Associate of the Institution and a participant in its program of social anthropology and linguistics. Dr. Gillin is to spend the summer of 1942 initiating studies among the Pokoman of eastern Guatemala. This group, concerning which there is almost no information, was briefly visited by Dr. Redfield and Dr. Tax in 1941. Dr. Gillin has been informed as to the special interest this Maya group have for the general project, with regard to their critical position in connection with the supposed dichotomy of the Maya peoples into lowland and highland divisions, their interest for students of Indian-Ladino relations, and the possible interrelation of market systems, or their absence, with other elements of Indian society. Dr. Gillin will, however, develop his research along such lines as seem most promising after his preliminary survey.

Melvin Marvin Tumin, a student of anthropology at Northwestern University, received a fellowship from the Social Science Research Council to enable him to acquire field experience in Middle American ethnology. This he will do in the eastern highlands of Guatemala, where his work will be supervised by Dr. Redfield.

While Mr. Samuel L. Bradshaw worked on the grammar of Yucatec left unfinished by Dr. Andrade at his death, Dr. Abraham M. Halpern continued the comparative

study of other Maya languages. His initial task was to examine and organize Dr. Andrade's field notes and to review all published materials bearing on the linguistics of the Maya and their neighbors, with a view to estimating the present state of the study and recommending a course to be pursued in carrying it forward. In the year just ended, Dr. Halpern went through the notes and catalogued the phonograph-

record material. With the kind assistance of Mr. Edward F. Sywulka, a dictionary file was started for the Mam language. A beginning has also been made on a comparative dictionary file. The work was discontinued when Dr. Halpern took leave of absence as of April 1, 1942, in order to undertake studies of an Oriental language important in connection with the war effort.

POST-COLUMBIAN AMERICAN HISTORY

HISTORY OF THE MAYA AREA

F. V. SCHOLES, R. L. ROYS

Mr. Scholes spent most of the past year in Albuquerque, New Mexico, with headquarters at the University of New Mexico. For several years the university, which is strategically located in an area which has strong historical and cultural ties with Hispanic America, has stressed Americanist studies, and in 1941 a School of Inter-American Affairs was created to give direction to this program. Mr. Scholes, who had been head of the History Department of the university prior to joining the Division of Historical Research of the Carnegie Institution, was invited to serve as Lecturer in History for the academic year 1941-1942 and to give a graduate course in the bibliography, methods, and problems of Spanish colonial history. Instruction in this course was given once a week for two hours throughout the year. Mr. Scholes also served at times as an adviser on problems relating to the general program of inter-American studies.

Research under the History of Yucatan Project was carried on as usual by Mr. Scholes and Miss Adams in offices at the university library. Progress was made in exploiting a large accumulation of archival materials from Spain, Mexico, and Yucatan, especially with reference to studies

being made in collaboration with Mr. Roys, and it is expected that these will be completed by the end of 1943. It was Mr. Scholes' intention to visit Yucatan between the first and second semesters of the university term, but this plan was abandoned early in December.

In October Dr. Chamberlain was granted leave of absence from the Carnegie Institution to permit him to accept an appointment as Senior Cultural Assistant at the United States Legation in Guatemala City. Consequently his work on the conquest of Yucatan has been temporarily suspended.

The employment of Sr. J. Ignacio Rubio Mañé terminated December 31, 1941. Since 1935 he had been engaged in archival investigations in Merida and Mexico City. As a result of his researches a vast amount of new documentary material relating to the history of the Yucatan Peninsula has been made available. In accordance with an agreement made in 1939 by Mr. Scholes and the officials of the Mexican National Archive, Sr. Rubio Mañé spent the past two years on an inventory of the Papeles de Bienes Nacionales section of the Archive, which contains almost 2000 bundles of ecclesiastical papers of the colonial period, notably materials for the archdiocese of Mexico City. The inventory, which Sr. Rubio Mañé completed in December, is

now available for use by all students of the colonial history of Mexico. Carnegie Institution wishes to take this opportunity to express its appreciation to the Director and other officials of the Mexican Archive for courtesies extended to Sr. Rubio Mañé and other members of the Division staff during the past few years, and to record its thanks to Sr. Rubio Mañé for his loyal service in connection with the History of Yucatan Project.

Much of the past year has been spent by Mr. Roys in the completion of a survey of the institutions and culture of the Yucatecan Maya during the period immediately preceding the Spanish conquest. New documentary sources discovered and made available by Mr. Scholes and a closer study of other Maya documents have been found to supplement and cast increasing new light on the published reports of the earlier Spanish writers.

Evidence is accumulating regarding a ruling class in Yucatan, apparently composed of families claiming to be descended from former Mexican invaders. This group not only controlled the political organization, but also monopolized the priesthood. Since a knowledge of hieroglyphic writing was confined to the priests and some other members of the nobility, we have an anomalous situation, in which the principal key to Maya science was in the hands of a class of allegedly foreign origin.

In contrast with conditions reported as widely prevalent in the highlands of Mexico, in at least four, and probably more, of the native states of Yucatan we find what appears to have been a genuine territorial government, in which the head of the principal town not only confirmed and controlled the heads of the other towns of his area, but also frequently put his own appointees into such positions. Although the local head acted in a judicial

capacity in his town, he was obliged to refer certain serious cases to the territorial ruler. Finally, the latter kept track of the boundaries of his state, inspecting them personally from time to time to prevent trespass on the part of aggressive neighbors. Other states, however, had no single ruler, but consisted of allied towns or groups of towns, in which the local head was likely to belong to the most prominent lineage group of the region.

A third point of interest emphasized by the more recently discovered source material is the extensive trade which existed between Tabasco, Yucatan, and Hibueras-Honduras, the last being the northern coast of what are now Guatemala and Honduras. Although the languages of the Maya stock largely spoken in all three areas were very similar, scattered Mexican-speaking colonies were also found in Tabasco and Honduras, which were especially active in trade. Notwithstanding such differences in language and culture as existed, commercial relations appear to have been so close that the three countries could well be considered a single economic area. Campeche people had trading posts on the Ulua River in Honduras, and the Chontal-speaking Acalans of southwestern Yucatan occupied an entire quarter at Nito, a famous commercial center near the mouth of the Rio Dulce. Generally speaking, the Yucatecan Maya exported cotton cloth, salt, honey, and slaves to their neighbors on either side and received in return metal objects, cacao, feathers, precious stones, and other luxuries. That these commercial relations created a certain community of interest is shown by the evidence of military alliances, which appear to have existed between some of the Yucatecan towns and those near the coasts of Tabasco and Honduras.

Many of the articles imported into Yucatan by way of Tabasco and Hibueras

came originally from the inland neighbors of the last two. Early in 1942 Mr. Roys went to Guatemala, where a study was made of the region in which Nito was said to have been situated, and of what appear to have been two of the most important natural trade routes into the interior. One was the Montagua River, on which merchandise could be transported by canoe to the foot of the rapids not far below Gualan. The other was the water route formed by the Rio Dulce, Lake Izabal, and the Rio Polochic. Passenger launches now operate on the latter from the sea to Panzos, beyond which the river is navigable for canoes as far as La Tinta. Cacao plantations were reported on both the Montagua and Polochic by the first Spanish explorers; and the maize land in the valley of the Polochic is still considered to be especially good. The navigable part of the Montagua furnished access to the Chorti country, and on the Polochic canoe traffic reached the Poconchi area and probably also the Kekchi. Regarding the Chorti, it is of interest to note that recent ethnological investigations indicate that their culture resembles that of Yucatan more than it does that of the western highlands of Guatemala (Year Book No. 40, p. 308).

Mr. Roys, in company with J. E. S. Thompson, visited a number of archaeological sites along the Pacific slope of Guatemala formerly occupied by Mexican-speaking immigrants. Many of these people were still living in various parts of the region at the time of the Spanish conquest, and a colony of them existed in central Guatemala. The language, known as Pipil, is still spoken in Salvador, but seems to have disappeared in Guatemala within recent years. Their sculpture has significance for the history of Yucatan because of its resemblance to that of the Mexican period in the latter country. In both cases, as Mr. Thompson has recently shown, var-

ious features of the culture reflected by the sculpture appear to have been brought from a common source in southern Veracruz.

Such analogies seem less noticeable in the western highlands of Guatemala, but here, as in Yucatan, native historical legends indicate that the ruling class believed itself to be descended from people who had come from the Gulf coast of Mexico. A considerable number of archaeological sites were visited in this region, particular attention being given to those which were occupied at the time of the conquest, among them Utatlan, Chuitinamit on Lake Atitlan, Iximche, Sacaleu, and Rabinal. The ruins of Rabinal are the best preserved, and its remains are imposing. Situated on a high, barren ridge above a large, fertile valley and well protected from attack by its location, the site consists of eight ceremonial plazas, two containing excellently preserved ball courts. One of the latter is set into the upper floor of a plaza which was laid out on two different levels. In each complex the most prominent buildings are a central temple and a long, narrow house at one end. Both are set on substructures and have walls of rough, flat stones laid in mud mortar but covered with a thick coat of lime plaster. The dimensions and general appearance of these buildings suggest that they had borne flat, beam-supported roofs. Although a number of house sites were observed on the slopes adjoining the plazas, the location is such that it seems unlikely that a large population resided permanently at the site.

At Salama, a short distance east of Rabinal, there was formerly a group of Mexican-speaking Indians, who have been completely absorbed by the local Ladino population. Two days were spent in questioning a number of the older people, who remembered this group, and a few of their Hispanicized descendants. It is of interest

to note that they were apparently little influenced by their Rabinal-Quiche neighbors. Although the latter, especially those of the near-by town of San Miguel Chicaj, have always visited the Salama market regularly, it is generally agreed that the local Indians had little to do with them.

Returning to the United States through Mexico, Mr. Roys visited Teotihuacan and Tula, the latter being of especial interest to the student of Yucatan because of the remarkable resemblance of the sculptures recently uncovered there to those of the Mexican period at Chichen Itza.

UNITED STATES HISTORY

L. F. STOCK, J. J. MENG

Volume V of Dr. Stock's *Proceedings and debates of the British Parliaments respecting North America*, a description of which was given in the last annual report (Year Book No. 40, pp. 310-311), was issued in the early autumn. Progress on the sixth volume of the series, which will begin with 1754, has not advanced to the point set for this year's work. As was to be expected, the war has greatly interfered with the normal use of the facilities of the Library of Congress. The Division of Manuscripts, in the hospitable shelter of which the work has been carried forward through all these years, was for a long time, pending its removal to new quarters in the Annex, closed to investigators. It was also found expedient to restrict the use of many of its collections, and to withdraw temporarily all stack privileges. The library officials, with customary kindness, extended every aid possible under the circumstances, but the emergency regulations have made it difficult to work with the materials at hand and impossible to put into final form the completed part of the manuscript for this volume.

Under these circumstances Dr. Stock has been devoting some time to the collateral reading of such documentary, biographical, and other works as will be useful for future annotation of the series or may contribute to the text. With the assistance of Mrs. Helen S. Tepper, he has also taken advantage of existing conditions to begin the organization of the files of the former Department of Historical Research. Under the direction of the late Dr. J. Franklin Jameson that department not only was engaged in a wider program of historical activities than at present, but also served as a clearing house for historical projects and inquiries. The correspondence, therefore, especially Dr. Jameson's remarkable letters, shows perhaps more than does any other existing collection the variety of American historical activities of those years. It is hoped that a collection of Dr. Jameson's letters will soon be published as an important chapter in the story of the development of American historiography.

During the year Dr. Stock has, as usual, answered many inquiries of students, and has placed at their disposal some of his parliamentary materials. He has served as chairman of the Committee on Publications of the American Catholic Historical Association and, as one of the latter's ex-presidents, on the Executive Council of that organization. In November 1941 he discussed the "Uses of government records" before the Federal Records Conference of the Society of American Archivists; and in December spoke before the Irish History Society of the District of Columbia on the "Transportation of Irish prisoners to the American colonies."

Work on the *Guide to materials for American history in the libraries and archives of Paris* was continued during 1941 and 1942 by Dr. John J. Meng under the

supervision of Dr. Waldo G. Leland. Volume II, dealing with the French Foreign Office archives, has been completed by the multilith process and is about to be released. Volume III is practically complete in manuscript form. This latter volume, originally planned to include only materials in the War Office archives, has been enlarged to include as well materials from the archives of the Comité de l'Artillerie, the Comité Technique du Génie, the Service Hydrographique, and the Ministry of Marine. The manuscript for volume IV should be completed before the end of

the calendar year 1942. It will include the Actes du Pouvoir Souverain relating to America, materials from the Archives Nationales, and a small amount of miscellaneous items from other depositories. The manuscript for the first part of this volume is now ready for the printer. The final volume of the series, volume V, will be devoted to the Archives des Colonies. Work on the manuscript for this segment, one of the largest and most complicated of the lot, will begin as soon as the earlier volumes are completed, probably by January 1, 1943.

HISTORY OF SCIENCE

GEORGE SARTON

Introduction to the History of Science. The manuscript of the first half of volume III, dealing with the first half of the fourteenth century, is now complete, but is delayed to permit the inclusion of the many hundred additions and corrections which will doubtless be encountered in the writing of the second part (covering the latter half of the fourteenth century). Since the first half runs to some 3000 typewritten pages, the revision involves considerable work in itself. Two chapters (out of fourteen) of the second half are already finished.

Editing of Isis. Volume 33, the first pub-

lished in America, has been issued. It is the largest and richest volume in the history of *Isis*, comprising 740 pages with many illustrations and including 41 papers, 54 notes, 85 reviews, and a bibliography of 1400 items. On account of increasing expenses, the capacity of *Isis* has been much reduced. It has not yet been possible to renew the publication of *Osiris*, for which much material has accumulated.

The proofreading and editing of *Isis* are taken care of by Dr. Pogo, who also conducts many minor investigations entailed by the editing and by the *Introduction*.

PUBLICATIONS

MARGARET W. HARRISON

The seventh volume of "Contributions to American Anthropology and History" (publication 528) has just been issued. In addition to Contributions 35 and 36, listed in the last annual report, the volume contains *Substela caches and stela foundations at Copan and Quirigua*, by Gustav Strömshvik (no. 37); *The Maya calendar of the Ixil of Guatemala*, by the late J.

Steward Lincoln (no. 38); and *Rio Grande glaze paint ware: a study illustrating the place of ceramic technological analysis in archaeological research*, by Anna O. Shepard (no. 39). Three manuscripts are scheduled for early appearance in volume VIII: *The archaeology of southwestern Campeche*, by E. Wyllys Andrews; *San Agustín, Guatemala*, by A. Ledyard Smith and

A. V. Kidder; and *The wall of Mayapan*, by Ralph T. Patton.

Toward the end of 1941 the Institution published Morris Steggerda's *Maya Indians of Yucatan* (publication 531) by the multilith process. This sociological study is based primarily on the town of Pisté, Yucatan.

Anasazi basketry, Basket Maker II through Pueblo III: a study based on specimens from the San Juan River country (publication 533), by Earl H. Morris and Robert F. Burgh, came from press in December 1941. The authoritative work on Southwestern basketry, it is a report on the vast collection covering the formative period of Southwestern culture, the only culture north of Peru where perishable materials have been preserved. A study on the sites of Durango, Colorado, which will add to the knowledge of Basket Maker culture, is planned by Mr. Morris for early publication.

The manuscript of *The Xiu Chronicle* is now complete in two parts: part I, "The history of the Xiu," by Sylvanus G. Morley; part II, "The Xiu Chronicle," by Ralph L. Roys. It will not be microfilmed as was formerly announced, but has been deposited in the Peabody Museum of Harvard University. Mr. Roys has adapted much of his material in this manuscript for presentation as a separate monograph, *Colonial Yucatan*.

To the five numbers of the new series "Notes on Middle American Archaeology and Ethnology" already published have been added this year *The prototype of the Mexican codices Telleriano-Remensis and Vaticanus A* (no. 6), by J. Eric S. Thompson, and *Observations on glyph G of the lunar series* (no. 7), also by Mr. Thompson.

It is expected that September 1942 will

see the publication of *Archaeological researches in the northern Great Basin* (publication 538), by L. S. Cressman, of the University of Oregon, and others. The problem of the history of early man in this area has been approached by some dozen cooperating specialists in the fields of anthropology, archaeology, paleontology, geology, and climatology.

Now being edited is the large monograph *Archaeological reconnaissance in southern Campeche and northern Guatemala* (publication 543). The introduction, summary, and description of the ruins have been written by Karl Ruppert; the epigraphy, by John H. Denison, Jr.

With the cooperation of Carnegie Institution, the University of Chicago Press published Robert Redfield's *The folk culture of Yucatan* in October 1941. Two manuscripts also in the field of social anthropology are ready for press: *The Maya of Quintana Roo*, by Alfonso Villa R., and *The economics of Panajachel, Guatemala*, by Sol Tax.

The preparation of the typescript of volume II of the *Guide to materials for American history in the libraries and archives of Paris* (publication 392) is almost finished. This book will be reproduced by multilith and released in the late fall of 1942. The material, covering the archives of the ministry of foreign affairs, has been compiled by John J. Meng, who is nearing completion of the manuscript for volumes III, IV, and V. This is the last in the series of guides to the sources for American history in the archives of foreign capitals to be published by Carnegie Institution. The manuscripts of the guides to Scottish and Dutch archives have been deposited in the Library of Congress.

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SPECIAL PROJECTS: HISTORICAL RESEARCH

MARION E. BLAKE, Bradford, Vermont. *Preparation of a monograph on ancient Roman construction based on the material accumulated by the late Dr. Esther B. Van Deman.* (For previous reports see Year Books Nos. 38 to 40.)

When the international situation made it clear that a return to Italy would not be possible for some years, it seemed advisable to change the plan for completing the work of the late Dr. Esther B. Van Deman on ancient Roman construction so that a volume could be ready for publication by the end of 1942. The scheme involves a cut through the two volumes proposed by Dr. Van Deman to present both the techniques and the historic background from the earliest times through the reign of Augustus. Five chapters have been prepared in accordance with the change of plan: "Squared stone construction in Rome and vicinity," "Sun-dried bricks," "Brick and tile construction," "Mortar," and "Concrete." Only two chapters remain to be written: an introductory chapter dealing with methods, based largely on Dr. Van Deman's preliminary articles,

and a concluding chapter giving in somewhat condensed form the chapters already written by Dr. Van Deman as the first part of her second volume. The chapters already covered by previous reports will have to be reorganized to fit the new plan. The inconsistencies and repetitions inevitable in a work carried on over a period of years will have to be eliminated, and all references carefully checked. Dr. Van Deman had to a certain extent chosen her illustrations from her large collection of personal photographs, but plates will have to be arranged and indexes made.

Whereas a final checkup in Italy would bring a greater precision in details, it would not, in Dr. Blake's opinion, change the essentials presented in this volume. At the present moment, it is impossible to tell whether the second volume can be written without a return to Italy.

PALEONTOLOGY, EARLY MAN, AND HISTORICAL GEOLOGY

JOHN C. MERRIAM, President Emeritus, Carnegie Institution of Washington. (For previous reports see Year Books Nos. 20 to 40.)

In activities of the past year it has been the purpose first of all to carry to completion projects of research which have been under way, but for which it had been difficult to obtain opportunity for field work or for study of sufficient scope to permit ultimate judgments regarding the problems under consideration. As a second type of activity, effort was made to advance certain important researches requiring cooperation of a number of individuals with common interests, but working in somewhat different fields. By this method it was desired to guarantee the continuation of these researches over a longer period than would be possible for work of any one person. As a third objective, the attempt has been made to review certain philosophical problems of scientific and human interest which represent the focusing of ideas from many aspects of geological and paleontological science, and for solution of which there must be a broad foundation of investigation and experience.

In 1942 a considerable percentage of investigations of the first group, which had been taken up in 1938-1939, have reached a stage at which one may assume that their further advance is guaranteed by the interest and activity of associated or co-operating investigators. Of these a number may be considered as having reached a place at which the research and its results have already become a part of history in this field of science.

Certain studies of the second group have required either additional financial support for field and laboratory work, or more extended or closer cooperation among students and institutions. Some

of these researches have also reached a point at which it may be said that they are rapidly taking their places in the group of studies for which the major contribution is now completed.

The third group of investigations, growing out of the thinking and experience of Dr. Merriam, either independently or with his associates, has reached a place at which it becomes desirable to define and shape the problems more precisely than has heretofore been possible.

In organization of certain features of work during the past year it became clear that there rests upon students of scientific problems a larger responsibility than has heretofore been recognized for interpretation of research results in terms of human interest; such as may influence our study of major social and governmental problems. With shift in magnitude and degree of complication in world problems there has been wider search for materials which may aid in our attempt to understand questions involving different types of nationalities and different points of view.

More and more there has been a tendency to recognize relation between the underlying laws which control in nature and the principles in evolution of human groups and of ideas. The view that man has become largely independent of nature has been replaced by recognition of the fact that with all that has developed in creative activity and knowledge on the part of man, we are still largely imbedded in nature, from which we receive not only the physical and biological foundations upon which human evolution is based, but the influence also of laws which

may guide in formulation of social organization and of ideas.

COOPERATIVE RESEARCHES ON GEOLOGY AND
HISTORY OF LIFE IN THE JOHN DAY
REGION OF OREGON

As has been indicated in earlier reports, one of the most extensive and at the same time most fundamental of the fields of research in this program is that relating to the history of life and the geological story of eastern Oregon as represented in the region of the John Day River. Begun in 1899 through cooperation with members of the staff of the University of Oregon, these studies have been carried forward over forty-three years with very few periods of interruption. This research, though initiated under the direct guidance of J. C. Merriam, has come to include activities of a considerable group of workers, a number of whom were students or associates in the paleontological and geological laboratories of the University of California. Although these researches have been carried on in the main independently, at the same time they have been so related that there is not only understanding among the workers, but mutual aid also.

The researches under way in the John Day area have included the broad studies of geology by J. P. Buwalda in cooperation with all the other investigators where their work has touched geological problems specifically. In the field of the history of life, Chester Stock and E. L. Furlong have devoted themselves for many years to research on the mammalian faunas with reference to structure, classification, and that time succession in the geological record which gives the evidence of evolution. Studies of the invertebrate life, representing mainly Mollusca, have been carried out by E. L. Packard, of the State College of Oregon, on the basis of many years'

work in the John Day region and on other related faunas found in western United States.

Investigation of the great series of important and beautifully preserved fossil floras of the John Day region has been conducted for a long period by R. W. Chaney as a special project involving not only classification and sequence of the plant life of that region, but its relation also to distribution and evolution of other fossil floras in the later formations of North America, eastern Asia, and Europe. In these studies there has also been taken into consideration the relation of changes in plant life as represented in the evolution of fossil floras to distribution of floras of the world at the present time.

A phase of the study of the John Day region which has developed in recent years, and looks toward higher human utilization of the results and also preservation of the materials for future investigators or for public education, is represented in the project now being advanced for protection of a considerable part of the geological section of the John Day region. This is so planned that a nearly complete sequence of formations will be seen in spectacular scenic presentation, such as serves to impress the visitor or the scientist with the important features of the geological story.

Researches of John P. Buwalda. Dr. Buwalda has continued to have the leading part in research on geology in its relation to the story of the John Day region. As has been indicated in earlier reports, he has done extremely careful detailed mapping of several large areas, including the most important sections of the John Day region proper. On these maps there have been placed the data bearing upon areal distribution of the formations, geological succession, structure, and crustal movements, as well as the relation of the geological section to steps in the history of life.

As one of the significant problems of correlation involving relation of the John Day region to other geological sections in the Northwest, Dr. Buwalda has been engaged also in accumulation of data bearing upon the paleontologic and geologic relations of the Ellensburg formation of eastern Washington and of other strata which have been thought to be Ellensburg occurring in that region. Vertebrate fossils have been obtained from a number of localities. During the past summer, studies were carried out also on occurrences of somewhat similar beds in some of which Professor George F. Beck, of the Central Washington College of Education, has obtained vertebrate remains. Comparisons were made with the typical Ellensburg beds. All the sedimentary deposits described were found to be typically of nonmarine origin, and all rest upon the Columbia River lava series. Over large areas in central Washington the exposures seem to indicate that these beds are the approximate equivalent of the typical Ellensburg. But there are probably also some younger formations in that region. The beds in White Bluffs, long thought to correspond to the Ellensburg and to be of Miocene age, have been known for some time to be Quaternary.

Dr. Buwalda noted a peculiar and as yet unexplained circumstance in that the Ellensburg formation of central Washington, of Upper Miocene or later age, and the Mascall formation of central Oregon, of Middle Miocene age, seem to bear the same relation to the Columbia River lavas upon which they both lie. It would be expected that the Ellensburg, presumably younger than the lavas, would lie either disconformably or nonconformably upon them. Several well exposed contacts of Ellensburg sediments upon lavas were examined with a view to determining the relations, but in each case the evidence

points to conformity. The stratification of the sediments at each locality is sensibly parallel to the uppermost lava flow, and commonly the upper flow still bears scoriae and flow breccia, suggesting that virtually no erosion of the lava surface occurred before it was buried by the sediments. It is also significant that the Ellensburg deposits contain very little basaltic material.

Dr. Buwalda has also examined a number of localities at which structure of the sequence of formations might be expected to give additional light both on the succession of geological stages in the John Day region, and on relation of the John Day geological sections to those of eastern and central Washington. These sections, such as that on the Columbia River between Roosevelt, Washington and The Dalles, Oregon, have given important information on the sequence in age of the deposits. Other studies, such as the examination of fault structure in the Picture Gorge Quadrangle and the mapping of structure in the Cretaceous of the Mitchell Quadrangle in the John Day region, have furnished extremely important data bearing upon the whole question of sequence of deposits and their structural relations.

Dr. Buwalda has also studied carefully the wonderfully exposed geologic section along the John Day River between Spray and Dayville with a view to considering possible inclusion of that region in the proposed park or parkway reservation. Consideration was given to the width of the territory to be included, to the features which would have largest interest and stimulus for the public passing along the highway, and to the dangers which would beset this scenic district if it were not protected in some form of reservation. Dr. Buwalda believes that the entire district from Spray to the Mascall Ranch should be included in the area which it is proposed to protect. Fortunately, since the

present activities of the population in that region are mainly agricultural, one may assume that danger to the scenery is not serious.

Researches of Chester Stock and E. L. Furlong. In the present field season it has been possible for Dr. Stock to make two visits to the region of earlier studies in eastern Oregon for work on problems of geology and paleontology of that area. These visits have covered both field work at localities of exceptional importance, where additional information has been needed, and conferences with other investigators concerned with sections of the John Day area. As result of these studies Dr. Stock has brought to the point of decision consideration of a number of critical questions relating to faunal zones, thus making possible conclusions which are being fitted into the program of interpretation of the geological sequence.

Dr. Stock has also given special attention to preparation of materials for a study of the history of life in this region, needed in connection with the plan for publication of a small book discussing the history of life and the appreciation of time as represented in the John Day section.

Mr. Furlong has continued his detailed study of structure, classification, and evolution of some of the most important mammal types of the John Day area.

Researches of E. L. Packard. Dr. Packard has assembled all the data and materials obtained in a long period of field and laboratory studies in preparation of a manuscript covering largely the sequence of form and evolution of the marine mollusks found in certain of the older formations of the John Day region. This series of studies gives a record of the life of the region from the earlier periods, represented largely by marine forms; these are followed by periods in which the fossil remains are largely those of land animals.

Dr. Packard has been effectively assisted by F. M. Anderson, of the California Academy of Science, who has placed his collections and the information available to him at Dr. Packard's service. At the same time the contribution of Dr. Packard in this cooperative work will undoubtedly help materially in certain of the studies which Dr. Anderson has had under way.

An important phase of Dr. Packard's study has been represented by the conferences which he has held with Dr. Buwalda on sequence of formations and geological structure of the regions in which the marine invertebrate faunas have been found.

Researches of R. W. Chaney. Some of the important results of investigations of R. W. Chaney on the history of floras in the John Day region can best be stated by the following quotation from a report based on his studies:

"Recently completed studies of two Lower Pliocene floras from northern Oregon emphasize the regional differences in vegetation which were becoming conspicuous in western America during later Tertiary time. The Troutdale flora from the western slopes of the ancestral Cascade Range includes such typically coastal genera as *Sequoia* and *Chamaecyparis*, whereas the Dalles flora to the east is made up largely of box elder, redbud, and other plants whose living equivalents now occupy stream borders in semiarid regions. Differences between these floras are less pronounced than those between modern forests on opposite sides of the Cascades, suggesting a lower topographic barrier during early Pliocene time. This is in accord with geological evidence that these mountains have been largely raised to their present elevation since the beginning of the Pliocene.

"Even during the Miocene epoch there were marked local differences in the vege-

tation of Oregon. The Mascall flora of the John Day Basin has swamp cypress, black oak, and hickory as its most abundant members; the Blue Mountains flora, from deposits of essentially the same age fifty miles to the east, is made up largely of beech, alder, and an oak which resembles the living *Quercus myrsinaefolia* of China; in the Stinking Water Basin, fifty miles to the south, black oak and alder are common, together with chinquapin and a conifer, *Glyptostrobus*, which has survived only in eastern Asia. These differences are interpreted as an expression of topographic diversity with its resultant climatic effects. They become even more pronounced over considerable ranges in latitude, as might be expected upon a planet the climate of which is primarily controlled by the sun.

"With any detailed study of the Tertiary vegetation of the past, from locality to locality in a restricted area, or from zone to zone over the continent, the whole idea of cosmopolitan floras becomes untenable. Doubtless there have been times of relative submergence when broad seaways reduced the effects of latitude upon climate, and when low relief brought more uniform living conditions and vegetation. But during the Tertiary period in western America, and particularly in its later epochs, there is little evidence of such uniformity. Progressive emergence and mountain building have brought about topographic and climatic diversity which have resulted in a wide range of forest types in the existing flora. Comparisons of fossil floras for purposes of correlation, either locally or over greater distances, must take into consideration the fact that floras differing from one another in many respects may still be of the same age if they lived under diverse climatic conditions. Only a knowledge of the vegetation of a given age over a wide area, a knowledge based on large fossil collections, will make pos-

sible the accurate interpretation of differences as well as similarities in the study of Tertiary plants."

PRESERVATION AND INTERPRETATION OF OUTSTANDING SCIENTIFIC AND SCENIC FEATURES OF THE JOHN DAY REGION

Future scientific and inspirational values of the John Day region of eastern Oregon will in considerable measure be determined by the possibility of protecting and interpreting that area in such manner that visitors can understand and enjoy the things of really great importance shown there.

Nature has preserved for us in the John Day area a remarkable record of geological history, of life, and of evolution. The stages in geological development have been such as to protect the major elements and at the same time expose them to view. As a result there is opportunity here to know certain aspects of the record of the earth not shown so clearly elsewhere. It is important to note that the region is not merely one in which the features have been opened to view in such manner that they can be examined easily. It must be realized also that even to the discriminating eye of science the story of the John Day region is one of exceptional significance and interest. There are expressed here characteristics found in many regions of the world, and with these a number of unusual features representing advanced steps in our knowledge of the way in which the earth was built, and in which life developed or evolved.

At a recent meeting of the Advisory Board on Educational Problems of Oregon Parks attention was given to the problem of finding means for protecting and interpreting a considerable area of the John Day region. The committee approved a program looking toward realization of

the project through utilization of sections bordering the state highway between the junction of the north fork and the middle fork of the John Day River and the Mascall Ranch above Picture Gorge on the middle fork. It was believed that the part of the region described is one of the most interesting natural areas of this country, and that the story which it tells in science, scenic values, and inspirational stimulus is one of the most important in America. It was considered that preservation of this region and interpretation of its values would be a service of the first order of importance, both in maintaining opportunity for important scientific work and in continuing the possibility for enjoyment of the scenic features.

Certain difficulties were recognized by reason of numerous and diverse ownerships of the land, but it was believed that cooperation among the agencies representing ownership would make possible the use of the most desirable features. It was thought that there might be such cooperation with owners of privately held lands that it would not be necessary to consider modification of activities on private ranches. It was suggested that, since the area follows a very fine Oregon highway, the region might be designated broadly as a parkway, with the state sponsoring the plan and with the State Parks Department perhaps serving as the administrative agency. Development of this idea is being carried forward as rapidly as possible, considering that with the relatively new point of view expressed, careful study must be given to means for realization of the project.

Attention is being given to preparation of a small book defining the features of the area which have special human interest, and giving such description as may make their value in the scientific, artistic, and human sense clear to visitors. It is

believed that such a book, if well written and illustrated, would stimulate interest and be an instrument of importance in guarding the region.

CONTINUED INTENSIVE RESEARCH ON THE RANCHO LA BREA LIFE SERIES

Although the conditions which have developed in the present emergency have limited certain aspects of the scientific program being carried on by many students in connection with the great fossil deposits at Rancho La Brea, it is important to note that significant progress has been made in the development of our knowledge of this remarkable record of life from the last geological period.

The program set up by the Museum of Los Angeles at Exposition Park for study of the fossil remains at Rancho La Brea has continued to go forward in such phases of the work as are looked upon as contributing ideas which have significance in our thought upon the meaning of history. Carrying out of the plan for an exhibit of materials on the site of their occurrence has been limited to some extent by reason of the need for application of materials in ways which are related to the defense program. But thought and planning as to how this exhibit may be organized to best advantage has not been interrupted completely, and we may assume that after this emergency a project of unusual significance will be developed by the Museum.

The principal guidebook relating to the occurrence and the collections from Rancho La Brea has been completely revised, and a fine new edition has been made available to the public.

Under the head of biological studies of the scientific materials obtained at Rancho La Brea, there has been advance in preparation of the monograph relating to the material concerning history of the camel

group in the period immediately preceding the present. These researches when completed will constitute one of the most significant contributions from the story of Rancho La Brea.

Life-size restorations have been made of some of the most important animals, such as the dire wolf (*Aenocyon dirus*) and the diminutive antelope (*Capromeryx minor*). These restorations, the work of Herman Beck and William Otto, have large value both on the scientific side and from the point of view of human interest.

One of the striking additions to our knowledge of the varied Rancho La Brea fauna is the group of fossil bird skeletons being restored by Eugene J. Fischer. To the group of mounted skeletons there has now been added one representing the large condor-like vulture (*Teratornis merriami*) and one of the extinct errant eagle (*Neogyps errans*). This collection furnishes for the first time an opportunity to visualize these important species in terms of size and bodily proportions.

Any reference to the Rancho La Brea fauna may properly include repetition of the statement that this collection of remains has important bearing upon the whole problem of history, as in considerable measure it crosses over the gap in time between the present and the period immediately preceding, in which the life world was in some respects similar to, and in other ways radically different from that of today.

EVOLUTION OF HIGHLY SPECIALIZED ANIMAL GROUPS CONTRIBUTING DATA OF EXCEPTIONAL INTEREST IN STUDIES ON EVOLUTION

Over a considerable period several groups of studies have been carried out for the specific purpose of obtaining data which would be of value in understanding

the manner of development or evolution of higher animals. Of these investigations, two have furnished material of special interest, one being an extensive series of researches by Remington Kellogg on history of the whale group, the other the relatively recent work of E. L. Furlong on evolution of the American antelopes.

Dr. Kellogg's study has had relatively high value in the whole field of biological studies, as we have an unusually satisfactory geological or historical record of the whale group of past ages. Being buried in the floor of the sea over a wide area of the earth's surface, and having a long evolutionary record over a considerable part of the world, the whales furnish exceptional material for studies on evolution. Also the whales have in the course of their history passed through a great number of stages, beginning with a type much like the modern carnivores of the wolf-cat group, passing through many stages including shore-dwelling carnivorous animals, and finally evolving into highly specialized animals limited entirely to life in the sea and illustrating very high specialization in aquatic life.

In the past year the work of Dr. Kellogg has been devoted in considerable part to study of the structure of the skull of embryonic whalebone whales. In adult whalebone whales the bones that comprise the brain case have been altered by slipping of one bone over another. In order to understand the development of this structure it has been important to make comparisons of the adult with the fetal skull; for there is reason to consider the possibilities presented by assumption that structure of earlier stages in history of this animal may be represented in the early embryonic stages of living forms. This comparison of the stages of development of the individual in a highly specialized animal with the stages of evolution as we

know them in the history of the group furnishes one of the most interesting bodies of fact for consideration in study of the general problem of evolution in the higher animals.

In the evolution and specialization of American antelopes, the most striking characteristics are restricted to a limited part of the skeleton. They seem, however, to show such a relation of the animal to its environment that the study may be seen to have value in researches on the meaning of evolution.

Investigations on the significance of variation and specialization in the American antelopes have been carried on through study of materials obtained in recent years by a group of researchers working upon the succession of geological formations in the middle and later Tertiary of north-western United States. Researches on the succession of antelope types found in these formations have been conducted for a considerable period by E. L. Furlong with the cooperation of Chester Stock and others. Added interest has been given to the work by reason of the fact that some of the steps in evolution of the American antelopes, leading up to appearance of the present-day pronghorn, resemble in a measure stages in evolution of the large and varied group of Old World antelopes within the same period.

In the past year Mr. Furlong has made considerable advance in study of these extinct antelopes, and with the use of abundant material he has been able to assemble portions of the skeleton which had previously been known only in part. The most interesting and important portions represent the skull, with the peculiar horn structures of this group.

With the cooperation of Chester Stock and the kind assistance of Childs Frick, it has been possible also to obtain the

assistance of William Otto in making what appear to be fully justified reconstructions of parts of the skull and skeleton, and especially the horn cores. The work of Mr. Otto, carried on with the fine touch of an artist and with precise understanding of anatomy and function of the parts of the skeleton involved, has made possible a contribution of the first order of interest. The reconstructions give a valuable picture of the history of the antelopes, and illustrate in a striking way the evolutionary stages of this group. As a result of the studies mentioned it has been possible to bring together a complete, though composite, skeleton of *Stockoceros*. With the material available it has been possible also to model the musculature and prepare a plaster cast approximately of life size. The same procedure was carried out for the small antelope *Capromeryx*. In addition to these forms, a series of seven heads has been modeled representing the various American antelopes available. These have been cast in plaster to show on one side the bones of the skull and on the opposite side the restored musculature. This collection of reconstructions, together with the abundant and well preserved original materials, constitutes collectively a group of materials of exceptional value in study of a highly specialized group of Tertiary animals.

A study of the materials representing the genus *Stockoceros* has been carried practically to completion in manuscript with illustrations. It is planned to bring this paper to publication in the near future.

Relation of the various stages in the history of these antelopes to the geological record has been worked out very carefully by Dr. Stock and Mr. Furlong, and further development of the geological and evolutionary story of the group is now being followed through field work.

STUDIES ON THE HISTORY OF EARLY MAN

Researches on early stages of human history extending into the geological period preceding the present have been continued in the past year by several investigators associated with projects under way for a number of years. The present world crisis, extending to practically every country and affecting in one way or another nearly every type of activity, has limited the possibilities of these investigations, but has at the same time called attention to the importance of improving our understanding of the origin and development of all the races of the world. It has become clear that without a better understanding of the origin of peoples and of their relationships we shall not be able to obtain that interpretation of relations among nations so urgently needed. Without clear understanding of problems of nation and race it will not be possible to set up a plan of world organization through which continuing and profitable peace can be guaranteed.

It happens that some of the most destructive war activities in the past year have affected regions in which there were under way investigations on the earliest chapters of human history. Among the most significant were those in the region of the East Indies and adjacent continental areas. The work of G. H. R. von Koenigswald in the region of the East Indies was carried on close to the beginning of the war period, but information is not available as to the present situation with reference to materials secured. Fortunately a paper by Dr. von Koenigswald, entitled "The South African Man-Apes and Pithecanthropus," has been published recently through the Carnegie Institution of Washington, and included in it is a considerable quantity of data representing recent studies on the *Pithecanthropus* ma-

terial from Java. Since the work done by Dr. von Koenigswald in cooperation with a number of other leading investigators represents some of the most important studies on the beginnings of human history that have been undertaken anywhere in the world, it is to be hoped that further investigation may be developed on the basis of his researches as early as the world situation permits advance of studies in this field.

The researches of L. S. Cressman, of the University of Oregon, in the field of early man in northwest United States furnish an important contribution to our knowledge of human history in America. The results of these studies have been brought together recently by Dr. Cressman in a paper entitled "Archaeological researches in the northern Great Basin," now in process of publication by the Carnegie Institution of Washington. The paper is an excellent illustration of cooperative research in which specific fields have been examined by specialists and the reports integrated for final presentation. This study shows (1) the presence of early man in south central Oregon and a culture related to the Cochise culture, and (2) on the basis of the present evidence, a culture in this region antecedent to the Basket Maker and early Lovelock Cave. It either is in the direct line of development of the Basket Maker or represents a parallel development from a common ancestral stock.

Dr. Cressman's contribution represents not only an intensive study of a very important region in Oregon, but with this a wide comparison with other localities and researches in America. The method followed has not only covered a detailed consideration of individual artifacts and groups of artifacts, but has also presented correlation of data involving the various regions and lines of evolution followed in western North America. Through coop-

eration of the Guggenheim Foundation it was possible for Dr. Cressman to study in the various museums of the United States the archaeological collections bearing upon problems presented by the collections secured in Oregon. He also visited collections at Boulder through the courtesy of Earl H. Morris, and spent some time with Ernst Antevs in southern Arizona, examining sites of the Cochise culture.

Dr. Cressman has prepared an illustrated brochure on "Early man and Crater Lake" for the National Park Service, to be used for distribution to park visitors. This paper brings together the results of archaeological research and the very significant studies made recently principally by Howel Williams on geological history of the Crater Lake region. A paper on results of research in Oregon under the title "Cave and lake bed cultures of southcentral Oregon" was read at the annual meeting of the American Philosophical Society in Philadelphia in April 1942.

Dr. Cressman sees the development of this research program as including studies concerning the hypotheses of Oregon Basket Maker relationships. The crucial areas for continuation of these studies are (1) northern Nevada along the Humboldt River into Utah and south toward the Four Corners, and (2) north into Washington and along the Columbia. A possible third would be the Snake River. It is believed that systematic work should be carried on in these areas for at least ten years in order to secure the full story of prehistory in this part of the Northwest and its relation to the Southwest.

RESEARCH ON MAJOR PROBLEMS OF THE GRAND CANYON

During a period of ten years or more in which study was being devoted to interpretation of features of the Grand Canyon

region which should be of major interest to visitors, special attention was given by the committee on cooperation with the National Park Service to the definition and interpretation of principal problems in the story of the Canyon. At the time this work was being done, one of the most distinguished investigators in the group made comment to the effect that in all probability at least half of the major problems presented by the Grand Canyon were not as yet sufficiently well understood to make possible an intelligent interpretation for the benefit of the public.

In the years that have followed, careful investigation has been carried on with the purpose of obtaining an understanding of those aspects of the Canyon which were assumed to be of special importance in a program of interpretation. The largest part in the conduct of this work was done by Edwin D. McKee, formerly of the naturalist staff of the Grand Canyon National Park.

As a result of his studies Mr. McKee has finished and published a considerable number of important contributions relating to the geology and other natural features of the Canyon. A part of this work has been done in cooperation with the Carnegie Institution, and publications by Mr. McKee have appeared in connection with the reports of the Institution. In the past year Mr. McKee has completed a very important work on the "Stratigraphy and ecology of the Grand Canyon Cambrian rocks," with which there has been presented a study on the fossils of the Cambrian prepared by Charles E. Resser, of the United States National Museum. These contributions together represent one of the most interesting pieces of research in the Grand Canyon within recent years. The material consists partly of detailed discussion of the formations and the life which they contain, and partly relates to

interpretation of certain major problems of the Canyon concerning which information has been furnished in earlier publications.

Among many significant features of marine sedimentation to be demonstrated by the detailed studies of Mr. McKee are those relating to the effects of transgression and regression by the sea. Information was obtained on the steplike manner of advance by the sea, on relative rates of transgression and regression, on the distinctive types of sediment accumulated under each of these conditions, and on the causes of the advances and retreats. Important data were obtained also on the interrelation between contemporaneous lithologic facies, on the repetition of the same sequence of facies during distinct periods but at varying points in space, and on variations in fauna with different lithologic facies of contemporaneous age.

Much of the detail and accuracy involved in the Cambrian studies of Grand Canyon has been made possible by the presence of excellent "key beds," including thin intraformational conglomerates, fossil horizons, and distinctive lithologic units that were traceable for many miles. With the aid of these it was possible to establish beyond reasonable doubt certain relations between lithogenetic units and planes of time.

The Paleozoic strata in the Grand Canyon are especially well adapted to the type of detailed study involving time and space that has just been completed for the Cambrian deposits. This is true both because of the excellent and continuous exposures over a wide area, and because the cross section through various formations is approximately at a right angle to the cordilleran geosyncline. Taking advantage of these natural opportunities and using comparable methods, the Coconino, Toroweap, and Kaibab formations were studied previously. Similar investigations of the

Temple Butte, Redwall, Supai, and Hermit are in various stages of development. This program, when finished, should bring out not only fundamental changes as related to time, but contrasts also in space as illustrated by transitions between and within different environments such as delta, dune, playa, and sea.

PRESERVATION AND INTERPRETATION OF EXCEPTIONAL NATURAL FEATURES

In connection with all field studies in past years on especially interesting features of geology and paleontology, attempt has been made to find ways for protecting these exceptional realities in nature for use in scientific work and inspirational influence. This principle is being expressed in the effort directed toward preservation of the large group of unusual natural features in the John Day area, described above. It has also been of influence in the movements to preserve and interpret important areas set aside for state parks in California and Oregon and for national parks throughout the country. Long experience with research, teaching, and conservation makes it clear that natural areas thus selected and interpreted have supreme value in advancing science of the future and for inspiration and enjoyment of the public.

Rapid advance of what we call the influence of civilization tends either to change completely or to modify markedly most of the natural areas that have attracted attention in the past. The movement to preserve what is needed for the future must therefore proceed at rapid pace in order to guarantee protection of the regions which are most important. In the effort to secure the safeguarding of such areas there has fortunately been extraordinarily fine cooperation among the groups of persons interested in the values of science, art, nature appreciation broadly,

and inspiration which may lead to lifting the level of intellectual and spiritual interest in the country.

It is now clear that the effort to preserve natural features must include the whole range of possibilities from protection of cliffs that may be destroyed for road metal, to forests and glades which, through use, may lose their original character.

CONTRIBUTION RELATING TO INFLUENCE OF NATURE IN HUMAN EXPERIENCE

Within the past year there has been brought to completion for publication a book entitled *Influence of nature in human experience*. The material considered in this volume represents studies extending over a period of more than twenty years, arising from results of fundamental research in many phases of science. The contribution of this publication represents in considerable part development of ideas concerning relation of science and of nature specifically to progress of human thought as discussed in reports of 1939-1940 and 1940-1941 under the head of philosophical and human problems growing out of research.

In this work the effort has been made to determine the extent to which our thought and life are influenced through principles suggested by conditions or activities of the natural world. Attention has been given to fundamental types of belief relating to conditions in nature as they are found in present-day philosophies or religions, and also to some that seem to have originated in past time through intensive study of features recognized in the expression of natural forces. The suggestion has been made that the reflection of what we see in nature appearing in our fundamental thinking indicates that we are in large measure affected by principles showing themselves in the world about us

through what we describe in science as natural law.

The attempt has been made also to point out the need for more careful study of basic principles arising out of natural law as they affect development of present-day peoples and their relations to one another. It is suggested that out of such a study relating to the fundamentals of human history it may be that we shall derive points of view of importance in the attempt to obtain a better understanding of world relations among existing peoples.

It seems, therefore, desirable, in the light of present-day knowledge, to inquire as to what influences of nature are of such type that they may be considered as affecting our thought and the evolution of our life. There is reason to believe that of concepts in science arising from study of nature, there are none that would be looked upon as having influenced our belief more deeply than the generalized principles concerning development or evolution, known to reach through vast ages in the story of the earth, and leading ultimately to development of human life and institutions.

As an outgrowth of the view of nature seen today through personal observation and through study of the ideas which organized science has produced, we are led to believe that this vision of life development affecting us so deeply tends to transmute itself ultimately into emphasis on what we call progress. It is also important to note that our thought is deeply influenced by what might be called the uniformity or universality of expression by laws or modes of procedure of nature in space and in time.

As result of this situation one notes that in studying the universe widely in space, and deeply in time, out of our developing experience there tends to grow an attitude toward life that gives perspective instead of

formless space, order in the place of aimless movement, confidence in the dependability of the universe and its laws, and faith that the world is so constructed as to maintain the trend of its development or evolution or progress.

Such an attitude toward this world and its meaning is enormously important to us when, as now, complicated dangers and evils seem almost to overwhelm us. This situation may be presented humanly by the statement that of conditions considered by us as exceptionally significant in shaping our lives, there would be almost universal appeal for guaranties of opportunity to make progress, and for the kind of security favorable for our advance. Such were the basic conditions for living defined in our Declaration of Independence. Life, liberty, and the pursuit of happiness are involved in opportunity and security. While realizing that the factors governing attainment of these situations may seem of temporary character, in general we are impressed by evidence indicating that the real controls are of long-time or permanent effect.

COOPERATION IN RESEARCH AMONG INSTITUTIONS OF AMERICAN COUNTRIES

For several years special attention has been given to the planning of cooperative activities in connection with researches involving projects in several of the American countries. Through the courtesy of Dr. Pedro C. Sánchez, Director of the Central Office of the Pan American Institute of Geography and History, in Mexico City, it has been possible to establish and develop cooperative relations involving a number of the countries, including Mexico and several Central American and South American nations. This relation has been set up with a view to obtaining the cooperation of investigators in different in-

stitutions and countries who are working upon widely distributed occurrences of materials or situations having close relationship. It has been shown that such studies make especially important contribution in advancing research, as this method brings cooperation of investigators with different points of view. Ultimately it gives a better understanding of the subject and develops favorable relations between countries which may not otherwise have close touch in science and research.

The investigations to which special attention has been given represent first of all fields of research comprised in the President Emeritus research program. The actual field work in recent paleontological investigations on the later faunas of southern North America has been carried out mainly by investigators from California Institute of Technology, and the results are now being prepared for publication. Students of similar problems in Mexico have cooperated in these researches. This program should bring into close relation investigators from a number of institutions in the United States and in Mexico, and will aid in determining where the most important materials can be obtained in such localities as will permit satisfactory identification of the geological horizons represented. It is believed that this method of cooperation will help very materially to increase the important data already available on the history or evolution of the higher animals in Central and South America.

The method which has been applied for paleontological work is also in effective use over a wide field of archaeological and anthropological research as carried forward by many institutions in Mexico and the countries of Central America. The cooperative work done by the various countries in these investigations, as for example that within the Republic of Mexico, has

resulted in very marked advance in knowledge of the history of interesting regions and in the contribution of important data bearing upon general historical problems.

Studies of various types in the field of geology, ranging from the succession and structure of geological formations to special problems of volcanism and seismology, have also been carried out on a cooperative basis, and give promise of extremely important results. The contributions being made have special value in that they not only represent the points of view of different institutions and individuals working in different countries, but also involve a synthesis of materials from closely or sometimes even distantly related subjects.

REVISION, REGROUPING, AND PUBLICATION OF MANUSCRIPTS ON SPECIAL SUBJECTS

In the course of the past year a large quantity of manuscript material representing articles or addresses written in recent years has been brought together in a separate office for special study. Although the materials in this collection of papers have been drawn upon to some extent for use in publication of larger papers, the greater part of it has not yet been put into print. As the problems represented are closely related to major types of research in recent years, it is important to review these articles with the idea of restating or regrouping the materials in such a way that they will make the best possible presentation of each problem. In some cases it is necessary to fit together parts of manuscripts that have been handled independently, with the idea of using the most important data in publication. In other instances, in which immediate publication

is not essential, manuscripts may be provided with explanatory notes which would be useful in any future study of these subjects. They may then be filed with the archive of correspondence and publications remaining in Washington.

ADDRESSES AND SPECIAL PAPERS

The following addresses have been delivered by Dr. Merriam:

"Importance of the historical record of Santa Barbara," Conservation Council of California, Santa Barbara, December 6, 1941.

"Cultural objectives and unity of American peoples," World Affairs Institute, Riverside, December 8, 1941.

"Biological and human implication of the coming of spring," Botanists of Southern California, California Institute of Technology, Pasadena, March 14, 1942.

"Geologic features as bases of major concepts in public education," Cordilleran Section, Geological Society of America, California Institute of Technology, Pasadena, April 17, 1942.

"Conservation of ideals," Garden Clubs of California, Pasadena, May 1, 1942.

"Nature and the religion of progress," Federation of Natural Sciences of Southern California, Los Angeles, May 7, 1942.

"Human values of the redwoods," message of the President to the Council of the Save-the-Redwoods League, San Francisco, August 20, 1942.

"Influence of nature upon origin and evolution of American pre-Columbian cultures," Mexico City, July 1942. Prepared for Symposium on Present-Day Culture of Mexico.

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